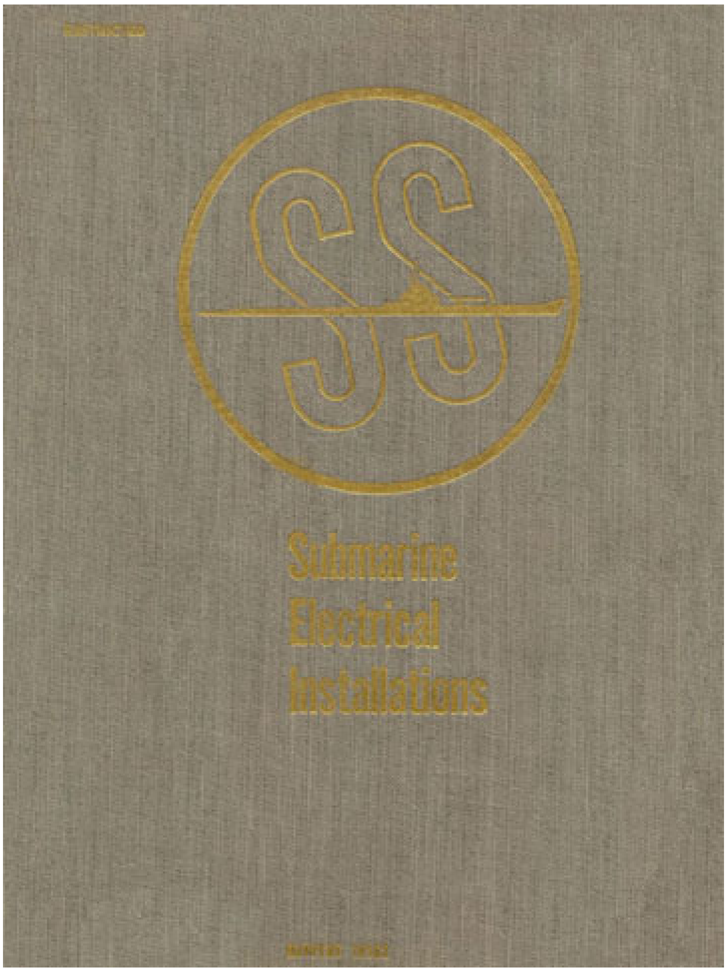
The Fleet Type Submarine Online
Submarine Electrical Installations



Folks,

Submarine Electrical Installations, Navpers 16162, is one of a series of submarine training manuals that was completed just after WW II. The series describes the peak of WW II US submarine technology.

In this online version of the manual we have attempted to keep the flavor of the original layout while taking advantage of the Web's universal accessibility. Different browsers and fonts will cause the text to move, but the text will remain roughly where it is in the original manual. In addition to errors we have attempted to preserve from the original (for example, it was H.L. Hunley, not CS Huntley), this text was captured by optical character recognition. This process creates errors that are compounded while encoding for the Web. Please report any typos, or particularly annoying layout issues with the Mail Feedback Form for correction.

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SUBMARINE

ELECTRICAL INSTALLATIONS

June 1946

~~RESTRICTED~~

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

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

PREFACE

The Submarine School, Submarine Base, New London, Connecticut, and other activities of Submarines, Atlantic Fleet have collaborated in the preparation of this manual.

All submarine machinery is operated directly by electricity generated initially from energy supplied by the ship's diesel engines, or indirectly through the transmission media of high-pressure air or hydraulic systems. A thorough knowledge of the theory, operation, and maintenance of the electrical machinery is a requisite to successful operation of the submarine and the fulfillment of her mission in life-the destruction of the enemy's ships wherever and under whatever conditions they may be encountered. The accomplishment of this mission necessitates that operating personnel be trained to maintain the machinery in reliable operating condition as well as to operate it correctly.

The purpose of this manual is to acquaint the student with the theory, operation, and construction of the components of the electrical installations. Special emphasis is Oven to the more important maintenance features and methods.

A thorough knowledge of the ship and its machinery may, in an emergency, be the means of keeping it and its crew in battle condition.

The manual is intended as a primary instruction manual, ashore and afloat, for officer and enlisted personnel having duties in connection with submarine electrical installations. For details of construction and maintenance, the manufacturer's instruction books and Navy Department manuals should be consulted.

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MAIN AND AUXILIARY POWER

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PART I

FLEET TYPE SUBMARINE
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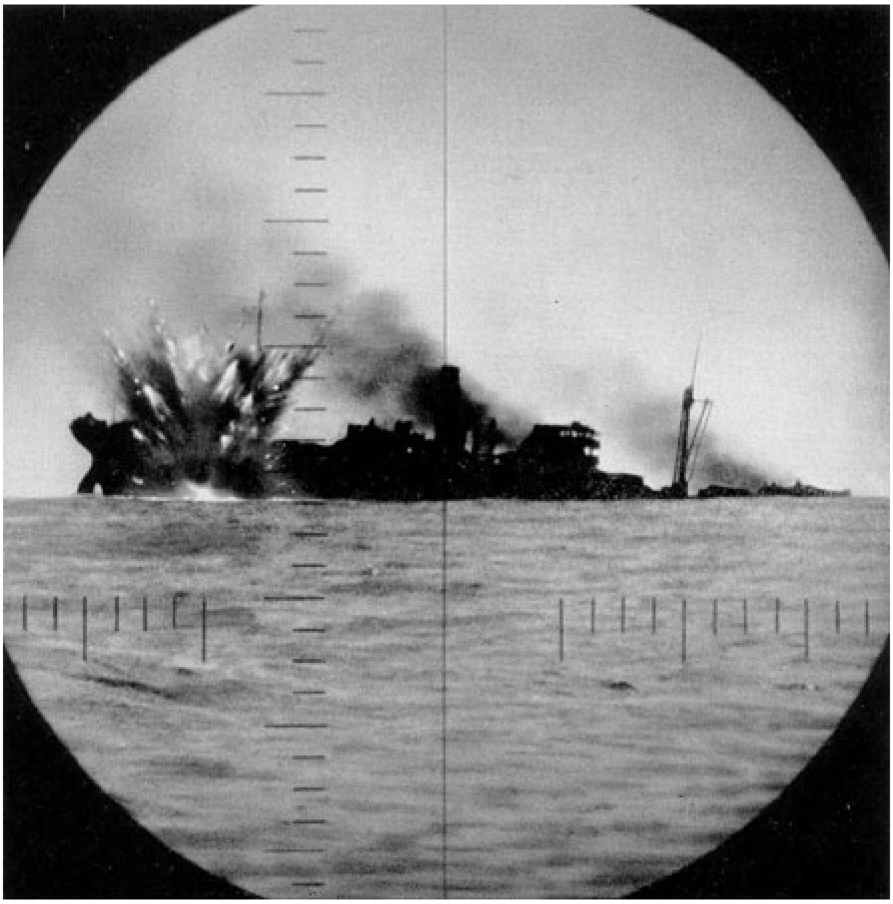

Electrical power helped do this.

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Version 1.14, 19 Oct 07

1
REVIEW OF ELECTRICAL PRINCIPLES

A. MAGNETISM

1A1. Natural magnet. The power of a certain kind of iron ore to attract iron was first discovered thousands of years ago. The attracting power of such ore was named magnetism, and a piece of ore having this power was named a magnet.

1A2. Artificial magnet. An artificial magnet is made by stroking a piece of hard steel or soft iron with a natural magnet. These pieces can then be used to magnetize others. However, the properties of soft iron are such that, although easily magnetized, it loses its magnetism almost as soon as the means of magnetizing it have been removed. Hard steel, unlike soft iron, is more difficult to magnetize but retains its magnetism. Hence, soft iron when magnetized becomes a temporary magnet and hard steel a permanent magnet. The extent to which these metals retain their magnetism is an important factor when they are used in electrical equipment.

1A3. Polarity. If a bar magnet is dipped into a pile of iron filings, the greatest number of filings adheres to the ends of the bar. The ends, where the attraction is strongest, are known as the poles of the magnet, while the fields, is the basis upon which electric motors depend for their turning motion. It is expressed in an important law of magnetic attraction which states: Like poles repel each other and unlike poles attract each other.

1A5. Magnetic field. When an ordinary bar magnet is held under a piece of paper on which fine iron filings are sprinkled, the filings assume the shape of curved lines (Figure 1-1). Holding the magnet perpendicular to the plane of the paper causes the filings to form straight lines toward the ends of the magnet (Figure 1-2). The action of the filings indicates the presence of a force. The space surrounding the magnet in which this force is apparent is known as its magnetic field. The lines in which the filings arrange themselves are called lines of force. The number of magnetic lines in the field represents a certain amount of magnetism which is expressed as a unit of quantity called magnetic flux.

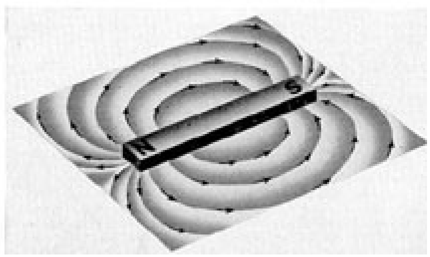


Figure 1-1. Lines of force surrounding a bar magnet.

center of the magnet, where there is no apparent attraction, is known as the neutral line, or equator. When this magnet is swung on a thread secured around its equator, one pole points toward the north and the other toward the south. The end which seeks the north is called the north, or positive pole and the south-seeking pole is called the south, or negative pole.

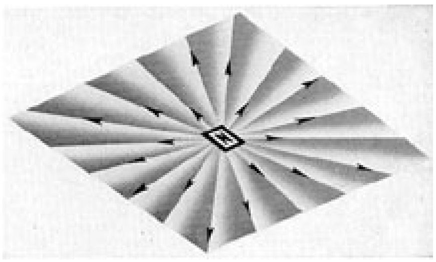


Figure 1-2. Lines of force surrounding the end of a bar magnet.

1A4. Magnetic attraction and repulsion. If a bar magnet is suspended from its equator so that it swings freely and the north pole of another magnet is brought close to each of its poles in turn, the north pole of the suspended magnet is repelled and the south pole is attracted. If the ends of the suspended magnet are approached by the south pole of the other magnet, the north pole of the suspended magnet is attracted and the south pole repelled. This power of attraction and repulsion, which all magnets possess for other magnets and magnetic

1A6. Magnetic circuits. A magnetic circuit is the path followed by the magnetic lines of force of a magnet. A closed magnetic circuit is one in which the lines of force produce flow around an unbroken metallic path or ring (Figure 1-3). Such a ring may be strongly magnetized and yet have no poles because its lines of force do not leave the metallic ring comprising the circuit. Ring magnetic circuits of this type are used where it is

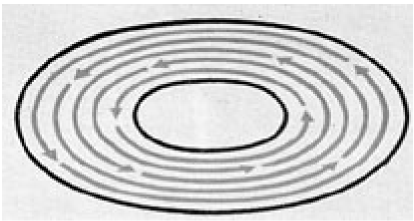


Figure 1-3. Closed magnetic circuit.

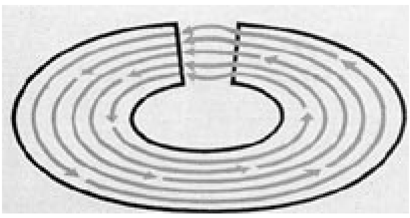


Figure 1-4. Open magnetic circuit.

required that little or no external field be present; for example, in transformers and certain electrical instruments.

When this ring is cut and opened slightly, two poles are formed at the cut (Figure 1-4). This is known as an open magnetic circuit and is the type used for magnetic circuits of motors and generators. In the case of a motor or generator (Figure 1-5), the lines travel from the north pole piece, across the air gap to the armature, through the armature core until opposite the next pole piece, across the air gap, through the south pole piece through the outside frame or yoke of the machine, and then to the field core from which it is assumed they started.

B. ELECTRIC CIRCUITS

1B1. Flow of electricity. An electric circuit is the closed path through which electricity moves. For explanatory purposes, the flow of electricity may be likened to the flow of water. In each case, the factors of current, quantity (the rate of flow), pressure (the factor which causes the flow), and resistance (the factor which tends to restrict the flow) must be considered.

Electrically these factors are expressed in the following units:

a. Ampere. The quantity of water flowing through a pipe is measured by the amount of water that flows through that pipe in 1 second, as 1 gallon or 3 gallons per second. Similarly, flow, or current, of electricity is rarely used because in most cases the quantity (coulomb) is of secondary importance to the rate of flow of electricity (amperes).

b. Volt. The quantity of water that flows through a pipe depends to a great extent upon the pressure under which it flows. Thus water pressure is measured in pounds per square inch. Similarly, the number of amperes, or coulombs per second of electricity, flowing in a conductor depends upon the pressure under which the electricity flows. The electrical unit of pressure is the volt.

The distinction between amperes and volts may be expressed as follows: Amperes represent the amount of current flowing through a circuit; volts represent the

measured by the amount of electricity that flows through a conductor in one second, as 1 coulomb or 5 coulombs per second. The gallon and coulomb are units of quantity. The ampere is a rate of flow equal to 1 coulomb per second. Hence, 25 amperes means a current flowing at the rate of 25 coulombs per second. The term coulomb is pressure which makes it flow. The voltage, or pressure difference between two points in an electrical circuit is sometimes referred to as the drop of potential or potential difference.

c. Ohm. The unit of electrical resistance is the ohm. A wire is said to have a 1-ohm resistance if a pressure of 1 volt forces a current

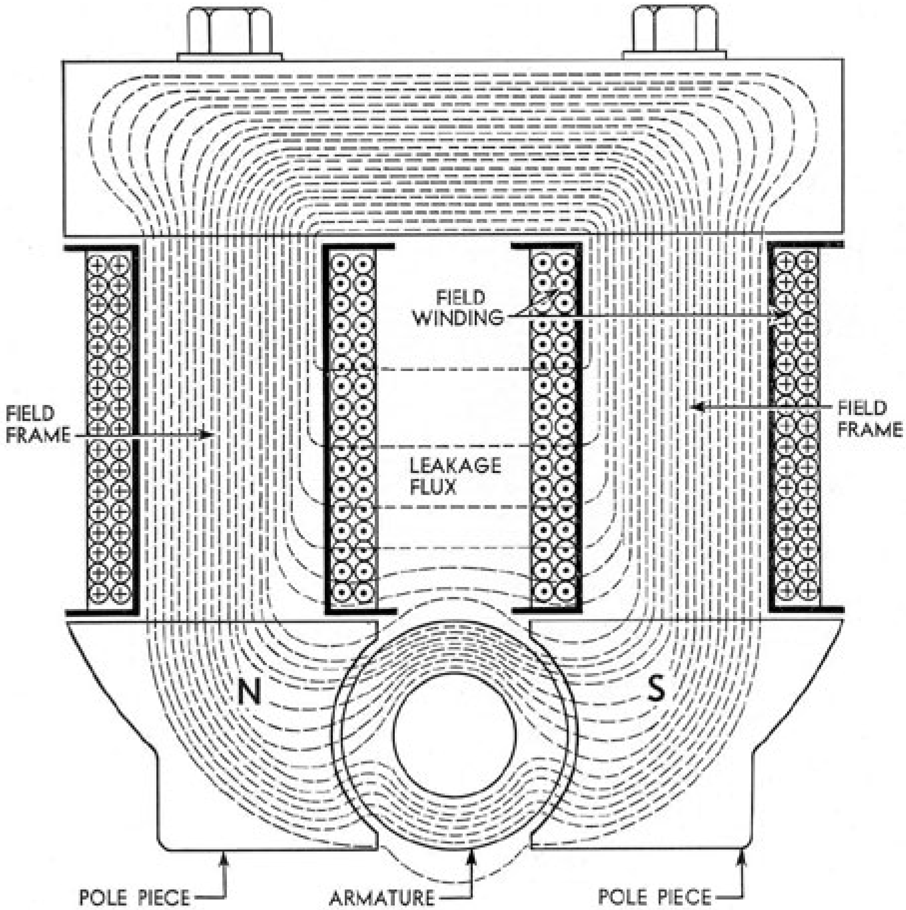


Figure 1-5. Magnetic circuit of a simple dynamo.

of 1 ampere through it. If the resistance of a circuit is 2 ohms, the current will be only half as large and only half an ampere will flow. The relationship, in direct current, between pressure (volts), current (amperes), and resistance (ohms) is expressed as follows: The electric current in a conductor equals the voltage applied to the conductor divided

Amperes = Volts / Ohms or

Ohms = Volts / Amperes or

Volts = Amperes X Ohms

This relationship always holds true when the quantities expressed are in the same system. Thus, if the law is applied to an entire circuit,

by the resistance of the conductor. This is known is known as Ohm's Law and may be simply stated as follows:

the number of amperes in the entire

circuit equals the number of volts in the entire circuit divided by the number of ohms of the entire circuit. If applied to a part of a circuit, the current in that part of the circuit equals the voltage across that part divided by its resistance.

It is possible to have a high pressure and no current. For example, when the path of a flow of water is blocked by a closed valve, there is no current, yet there may be a high pressure. Similarly, if the path of electricity is blocked by an open switch, there is no current (amperes) although the pressure (voltage) may be high. Thus, the amount of current depends upon the resistance that blocks the path; in this case, the closed valve or the open switch. The greater this resistance, the less the current which will flow under the same pressure.

1B2. Series circuit. A series circuit (Figure 1-6) is one in which all the component parts are so connected that there can be but one path through the entire circuit in which current can flow. The resistance of the circuit is the sum of the resistances of its component parts.

The voltage of a series circuit equals the algebraic sum of the voltages of its component parts. Thus, the amount of voltage that must be impressed on a series

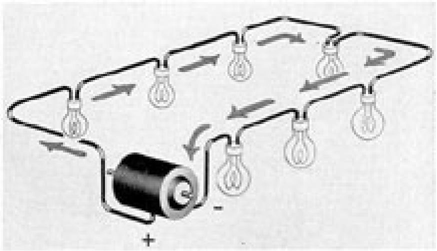


Figure 1-6. Series circuit.

circuit, is a circuit in which all components are arranged so that the current is divided among them. This type of circuit is generally used in connecting light and power loads. The principal distinction between the series and parallel circuits lies in the fact that in a series circuit the current value is maintained as a constant and the voltage is adjusted to the load requirements; whereas in a parallel circuit the voltage remains constant while the current value varies as more units, that is, more parallel paths, are cut in or out.

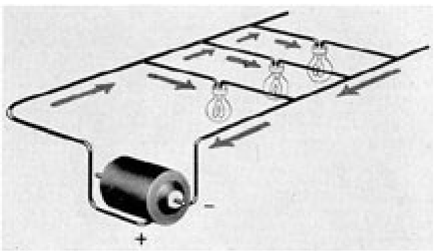


Figure 1-7. Simple parallel circuit.

circuit to obtain a certain flow of current can be obtained by first ascertaining the number of volts required by each component and then adding these voltages to find the total voltage required. The current in a series circuit is the same at all parts of the circuit.

1B3. Parallel circuit. A parallel circuit (Figure 1-7), sometimes called a multiple or shunt

C. ELECTROMAGNETISM

1C1. Magnetic field around a wire. The relationship between electricity and magnetism, which is the basis of the operation of nearly all electrical machinery and measuring instruments, was discovered by a physicist named Oersted. He found that a wire carrying an electrical current exerts an effect on a magnetic needle held near the wire. This is an indication that a magnetic field exists around the wire. The existence of this field can be demonstrated by passing a wire vertically through a piece of paper on which fine iron filings are sprinkled. When current flows through the wire, the filings arrange themselves in a concentric circular pattern around the wire (Figure 1-8). The needle of a compass placed on the paper points in the direction of the field (shown by the direction of the arrows in Figure 1-8). When the direction of current flowing through the wire is reversed, the shape of the field remains the same, but the direction of the compass needle is changed by 180 degrees.

The field intensity in both cases depends upon the strength of the current and the distance of the compass from the conductor.

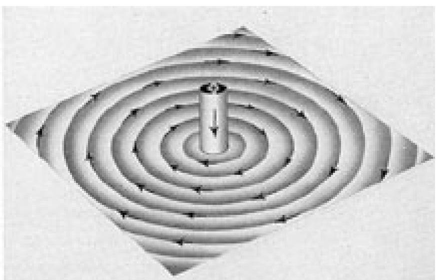


Figure 1-8. Magnetic field around a conductor.

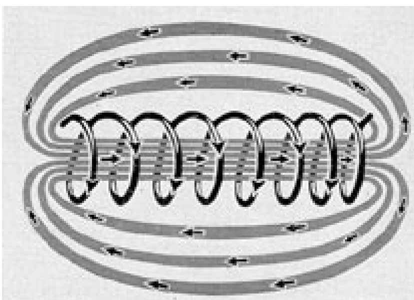


Figure 1-10. Magnetic field around a coil of wire.

1C2. Solenoid type of electromagnetic field. When a wire is formed into a single loop and a current is passed through it, a field exists around the loop. The intensity of the field varies with the strength of the current. The field has a north and south pole and acts in exactly the same manner as that of a bar magnet. The circular lines of force around the conductor curl around it in the same direction, entering at one face of the loop and leaving at the other (Figure 1-9).

If several turns or loops of wire are wound to form a loose coil (Figure 1-10), most of the flux lines produced by each of the turns will encircle the entire coil instead of encircling only the turn that generates them. This results in a field shaped similarly to that around a bar magnet. A temporary magnet therefore can be produced by passing an electric current through a coil of wire. This is known as a solenoid. The direction of the magnetic flux inside a solenoid can be found by grasping the solenoid in the right hand with the fingers pointing in the direction of the current flow. The thumb will then point in the direction of the magnetic field inside the solenoid.

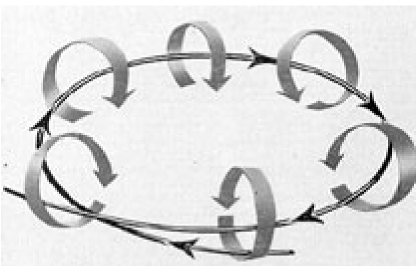


Figure 1-9. Magnetic field around a single loop of wire.

1C3. Electromagnets. A very powerful magnet can be made by inserting a piece of soft iron through which a current is flowing into the air space of a solenoid (Figure 1-11). Such a magnet is called an electromagnet. The direction of the lines of force in an electromagnet is the same as through the solenoid alone but the number of lines is increased tremendously by the ability of the soft iron to carry magnetism. The number of lines produced depends upon the current passing through the solenoid and the number of turns or loops in it.

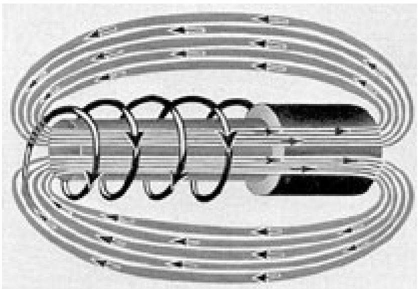


Figure 1-11. Magnetic field around an electromagnet.

In practically all electrical apparatus in which motion occurs, the motion is produced by magnetism. The chief advantages of an electromagnet are: 1) it can be turned on or off; 2) the strength can be varied; and 3) the movements can be controlled by controlling the current.

D. ELECTROMAGNETIC INDUCTION

1D1. General. The operation of motors or generators is dependent on the principle of electromagnetic induction discovered by Faraday. This principle is based on the induction of an electromotive force (emf) in a wire. An electromotive force is the force that establishes the electrical pressure or voltage that will cause current to flow if the circuit is complete. An electromotive force can be induced in one of three ways: 1) by pushing or withdrawing a magnet through a coil of wire; 2) by winding a coil around an iron rod, and magnetizing and demagnetizing the rod by another coil from a separate current source; or 3) by passing a conductor through a magnetic field in such a direction as to cut the lines of magnetic flux.

In the first method, the emf developed is induced by a change in the number of magnetic lines threading through the coil. In the second case, when the separate circuit is closed, a momentary current is produced which in turn sets up lines of force to oppose the producing field. The third case is that of a generator, which is described in detail below. The emf and current so produced are called the induced emf and current.

1D2. Principle of the simple generator. If a conductor is moved downward (Figure 1-12) so as to cut the lines of force between unlike poles of magnets, an electrical current-detecting instrument connected When the conductor is moved upward, cutting the lines of force in the opposite direction, the detector shows a deflection in the opposite direction, proving that the emf produced is acting in the opposite direction to the previously induced emf. The amount of deflection, or the value of the emf produced, varies with the rate at which the conductor cuts the lines.

When the conductor is moved horizontally from pole to pole, no lines are cut, since the direction of motion is parallel to the lines, and no deflection is produced. Thus, it is evident that the direction of the emf produced depends upon the direction of motion of the conductor. The value of the emf induced is proportional to the speed at which the conductor cuts the lines. The reason for the direction of the motion of the emf is stated in Lenz's Law as follows: Electromagnetically induced currents always have such a direction that the action of the magnetic fields set up by them tends to oppose the motion which produced them. This law will become more meaningful after a study of motor action (Section 1F1).

The principle of a moving conductor cutting a magnetic field is applied in the operation of direct current generators and motors, the conductors being positioned in slots around the armature which is rotated between the poles of electromagnets.

1D3. Generation of an alternating electromotive force. An alternating emf is produced by

to the ends of the conductor will indicate that an emf sufficient to produce a measurable current has been set up in the circuit.

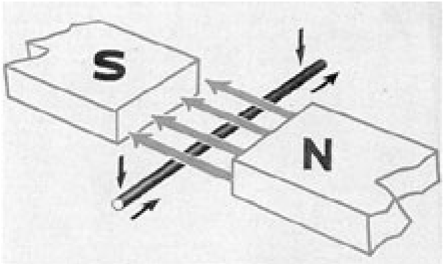


Figure 1-12. A conductor cutting lines of force.

continuously moving the conductor up and down, cutting the lines of force (see Figure 1-12). A detector in the circuit would indicate that the emf thus induced tends to cause the current to flow first in one direction and then in the other.

Figure 1-13 (reading down) illustrates the production of a simple alternating emf as a coil or loop of wire is revolved in a field between two magnetic poles. The loop consists of two conductors joined at one end and connected to two slip rings which are insulated from each other and from the spindle on which they are mounted. The circuit is completed by a resistance known as the external circuit which is

connected by sliding connections, called brushes, to the two slip rings.

If this loop is turned on its spindle so that the conductor A cuts the lines of force in a downward direction, and conductor B cuts them in an upward direction, the emf produced in the two arms of the loop would be in opposite directions, but since the two arms are connected in series, the resulting current flows around the completed circuit.

In position 1 (Figure 1-13), no emf is produced, since no lines are being cut, but as the plane of the loop becomes more horizontal, the number of lines cut per second increases until the maximum emf (position 2) is produced. As position 3 is reached, the number of lines cut decreases until the emf produced is again zero. As position 4 is reached, the emf again increases to maximum, but acts in the opposite direction in the conductors to that shown in position 2 because the conductors are cutting the lines in the opposite direction. Finally, in position 1, the emf produced is zero again and the cycle is back at the starting point.

The current maintained by such an emf is known as an alternating current and the arrangement producing it is called an alternator.

1D4. Generation of a steady electromotive force. An alternating emf is not suitable for all forms of electrical work. It is

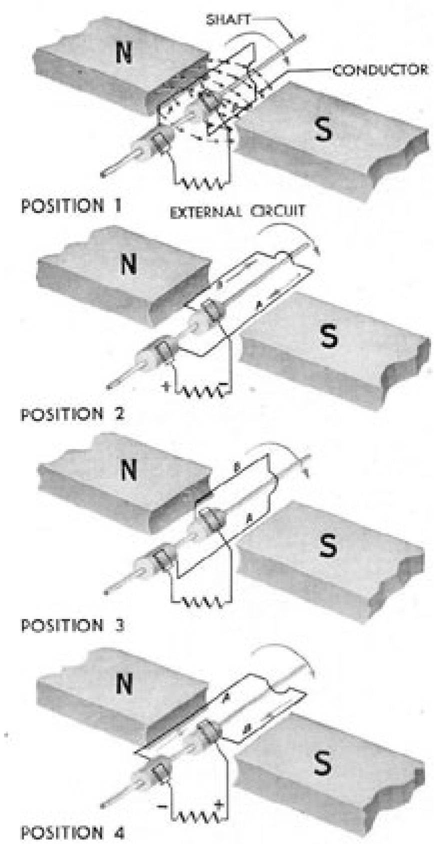


Figure 1-13. The simple alternator in four positions.

necessary therefore to produce an emf that has the same direction constantly. This is accomplished by the use of a commutator which serves to interchange the connections between the conductors and the outside circuit each time the direction of the emf induced in the conductors reverses. The commutator is arranged so that the brushes pass from one commutator segment to the next only at the points where zero emf is being generated. A simple two-segment commutator is shown in Figure 1-14. (A detailed description of a commutator is given in Section 1E8.)

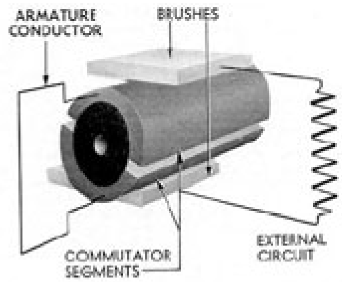


Figure 1-14. Sectional view of a two-segment commutator.

1D5. Multipolar field. Up to this point it has been assumed that the conductor is in a magnetic field in which the lines of force are practically parallel, such as would be found between a single pair of magnetic poles.

Instead of rotating in such a field, the conductors usually rotate in a field created by

several pairs of poles spaced evenly around the circumference of a circle. Such a field, produced by more than two poles, is known as a multipolar field.

In the four-pole field (Figure 1-15), each conductor goes through a full cycle in half a revolution instead of in a full revolution as previously described. As in the case of a conductor rotating in a two-pole field, when the conductor reaches a point midway between two adjacent poles, it is moving parallel to the lines of force and hence no emf is being generated.

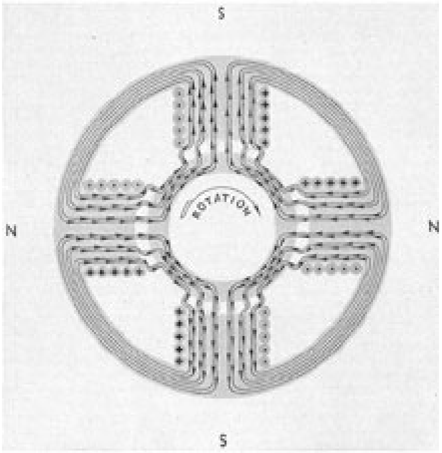


Figure 1-15. Multipolar field.

In Figure 1-15 it will be noted that the direction of current in the field coils is represented by the symbol (+) on one side and (.) on the other side. These may be thought of as the feathered tail of an arrow (+) disappearing into the page, and the point of the arrow (.) appearing through the page.

E. DIRECT CURRENT GENERATORS

1E1. Definition. A generator is a machine used to change mechanical energy into electrical energy by utilizing the principle of electromagnetic induction (Section 1D1). The principal parts of a direct current generator and their functions are described below.

1E2. Field structure. The field structure (Figure 1-16) consists of the field frame, or yoke; the field poles, or pole pieces; and the field coils. The assembly produces the magnetic field necessary in every generator.

The frame is usually a large ring of formed, or cast, steel or iron which supports the field poles and coils in its inner diameter strap coils wound around the field poles through which current is forced to produce the magnetic field. Two distinct types of field windings known as shunt and series are used.

1E3. Shunt generators. In a shunt generator the field coils are connected in series with each other and the complete shunt field circuit is connected in shunt or parallel with the armature circuit (Figure 1-17). The coils are composed of many turns of fine wire. The resistance of the coils is comparatively high, to prevent the field from taking too much current from the

and has feet on its outer surface to support the machine on its foundation.

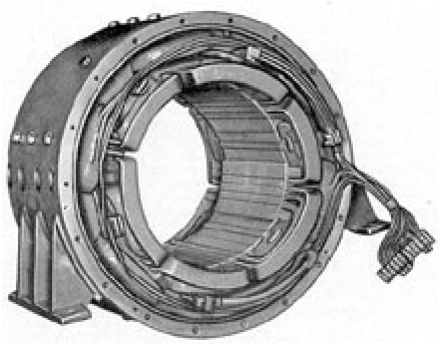


Figure 1-16. Field frame of a generator.

The field poles or pole pieces are constructed of laminated steel sheets and are bolted around the field frame. The arrangement of the poles around the frame is always such that they alternate in polarity. The ends of the poles may flare out to increase the surface that faces the armature, thereby providing better distribution of the flux. This flared portion also serves to hold the field coils in place and is sometimes referred to as the pole shoe.

The field coils are the insulated wire or

armature circuit. Many turns of wire must be used in order to obtain the necessary ampereturns which determine the strength of the magnetic field produced. The voltage produced by a shunt generator is practically independent of the current taken by the external circuit.

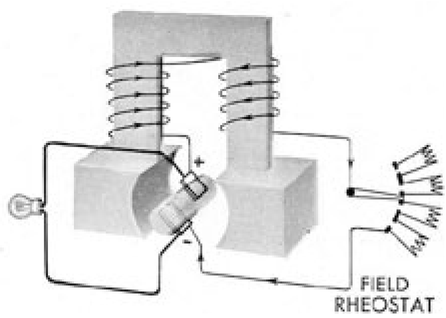


Figure 1-17. Diagram of shunt generator connections.

1E4. Series generators. In a series generator the field is connected in series with the

strength to overcome the slight decrease in voltage with increased load of a shunt machine. When wound in the opposite direction, it may be designed to give a definite voltage drop with increased load. This feature is desirable in certain applications, notably submarine auxiliary generators.

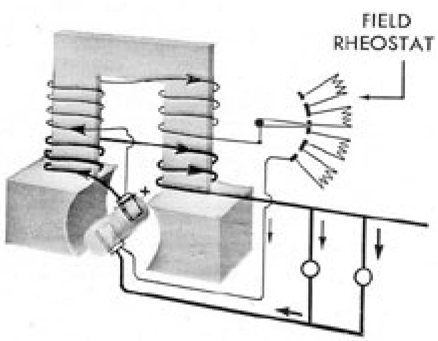


Figure 1-19. Compound generator connections.

1E6. Methods of excitation. Generators are termed self-excited when the field coils are energized

armature and the external circuit (Figure 1-18). The coils consist of a few turns of heavy wire having a low resistance in order to carry the whole current from the armature to the external circuit. In a generator of this type, the voltage increases as the load increases, for when more current is taken from the machine, more goes through the field coils, thus causing a stronger magnetic field.

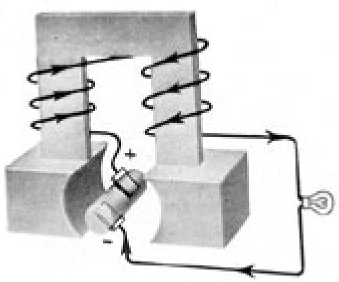


Figure 1-18. Series generator connections.

1E5. Compound generators. A compound generator has both shunt and series fields wound on the same poles (Figure 1-19). When wound in such a direction that it helps the shunt field, the series may be designed to have just enough

by current from the generator itself, or separately excited when the field coils are energized by a source outside the generator. Main propulsion generators on submarines are shunt wound and separately excited, the current to the fields being supplied by the battery. The voltage is controlled through a variable resistance in series with the shunt field. The voltage, being dependent on the strength of the field, can thus be regulated by weakening or strengthening the field by means of this resistance which is known as the shunt field rheostat.

1E7. Armature. The armature (Figure 1-20) of a generator is composed of the winding in which the emf is induced and the structure that supports this winding. This structure is made up of a number of slotted steel punchings assembled in the form of a cylinder and mounted on a spider. The spider is then attached to the armature shaft. On small machines the armature laminations may be mounted directly on the shaft. The windings are shaped to fit in the slots and are held there by means of wedges and steel banding wire.

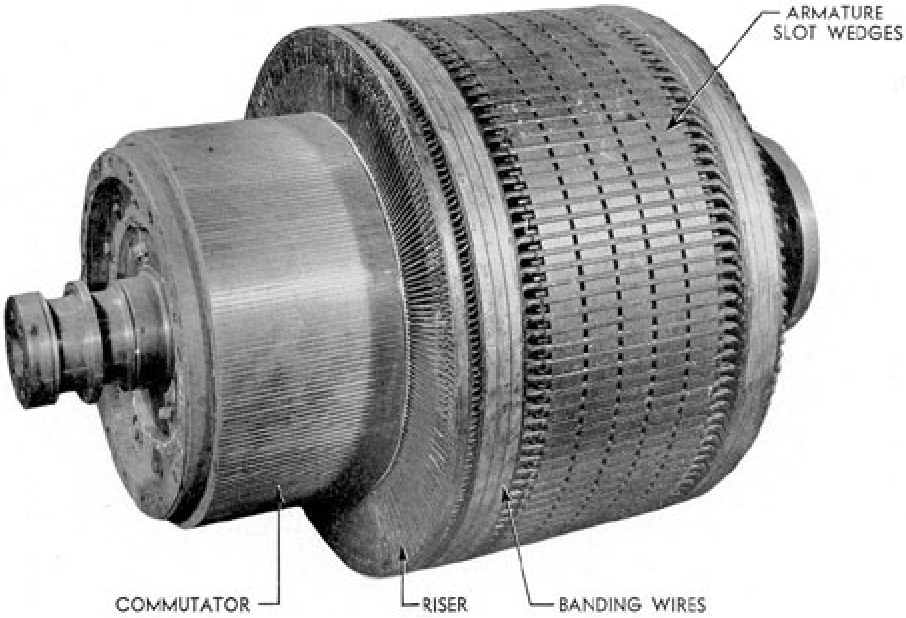


Figure 1-20. Generator armature.

1E8. Commutator. The commutator (see Figure 1-20) is a cylindrical form mounted on one end of the armature shaft. It performs the function of changing an alternating emf to a direct emf. It is built up of a number of longitudinal segments of copper which are insulated from each other and from the armature shaft that supports them. The number of segments is proportional to the number of coils in the armature, each of which is connected to the segments in a sequence determined by the particular type of armature winding.

1E9. Brushes and brush rigging. The brushes bear upon the commutator, collect the current from the armature winding, and lead it to the external circuit. The brushes are supported on holders which in turn are bracket-mounted around the inner diameter of the brush yoke. The complete assembly is known as the brush rigging (Figure 1-21).

The brushes are secured in the rigging in definite positions insure sparkless commutation over the range of loading. Adjacent groups of brushes in large machines usually are staggered axially so that the commutator will wear evenly. Provision is always made to permit rotating the brush rigging with respect to the commutator in order to pick up the best plane of commutation. This provision also permits rotation of the rigging so that brush holders may be brought to an accessible spot for maintenance or renewal of the brushes.

1E10. Armature reaction. The current flowing in the conductors of the armature sets up a magnetic field which tends both to weaken and to distort the main field set up by the shunt field windings. This effect is illustrated in Figure 1-22 which shows progressively: A, the main field; B, the field resulting from current in the armature conductors; and C, the field resulting from the combination of these two fields. Since the strength of the field is in part due to the armature current or load current, the resultant field C will vary both in strength and position as the

around the commutator to

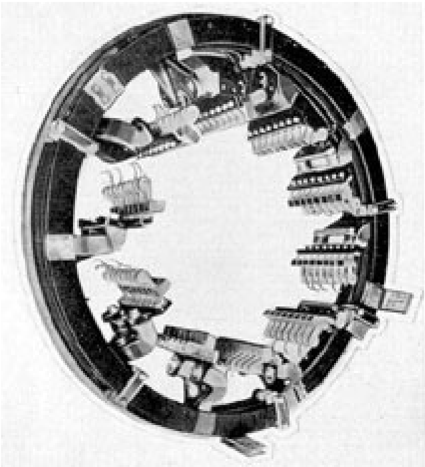


Figure 1-21. Generator brush rigging.

load current flowing through the armature changes.

A requirement of good commutation is that the brushes short circuit the commutator segments at a time when there is no induced current flowing in the conductors to which they are connected, or, in other words, that the brushes pass from one commutator segment to the next when the conductors of the armature to which they are connected are moving parallel to the field responsible for inducing the current. This position is called the plane of commutation, or the neutral plane. Obviously, this neutral plane shifts in position with change of load current. If the machine were to operate at constant speed and load, and always in the same direction, the brushes could be shifted to the neutral plane position and left there with good commutation thus effected. Such a machine is rarely encountered and in any case would not meet neutral plane in a fixed position throughout the range of load and speed of the machine, and, in the case of motors required to run in reverse, in both directions of rotation.

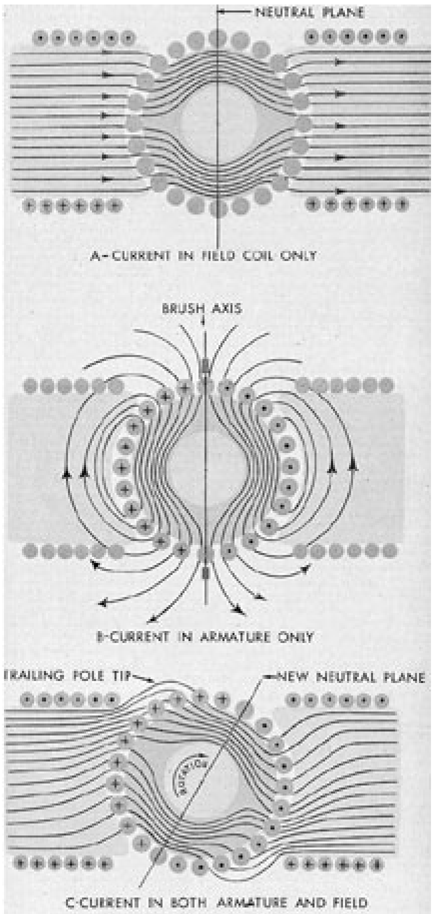


Figure 1-22. Effect of armature reaction on field of generator.

1E11. Commutating field windings. The commutating fields, or interpoles, as they are sometimes called because of their position relative to the main poles, consist of a series of small poles similar to the main field poles in construction and method of fastening, but

the requirements for submarine propulsion.

Since it is impractical to shift the brushes with each change of load, direction, or speed, recourse is made to auxiliary fields called the commutating fields and the compensating windings. The effect of these fields counteracts the effects of armature reaction and maintains the

having a winding that consists of a few turns of heavy copper bus bar of high current capacity and low resistance (Figure 1-23).

The commutating pole windings are all connected in series with each other and with the armature circuit. A resistor connected in parallel with the commutating pole windings is adjusted and permanently set at the factory to give the commutating pole strength that results in the best commutation. Most of the armature current goes through the commutating pole windings; only a small amount goes through the shunting resistor. Since the armature reaction increases when the armature load current increases, and the effect of the commutating poles also increases, the result is that the neutral or commutating plane is maintained in a fixed position throughout the load range.

With this method of correction, some distortion of the field still remains because the commutating fields, being small, as the compensating windings, is used in high-power d.c. machines. These windings consist of a few turns of low-resistance copper bar laid in slots in the faces of the main shunt field pole pieces and so connected that the windings carry current in the reverse direction to that of the immediately adjacent armature conductors. The compensating windings are connected in series with each other and with the armature winding in a manner similar to the commutating windings so that they also oppose the field set up by armature reaction. The current in them is then equal to that in the armature (Figure 1-25).

The field resulting from the compensating windings is wide in comparison with the commutating fields but weaker since the flux is less concentrated. The effect of the two windings acting in conjunction is to neutralize completely the effects of armature reaction in respect to the shifting of the neutral plane, and to eliminate almost completely the distorting effects. Thus it is insured that the

are not completely effective in correcting the distortion in the vicinity of the main pole tips. This latter condition is especially true of the high-power, compact machines used for submarine propulsion.

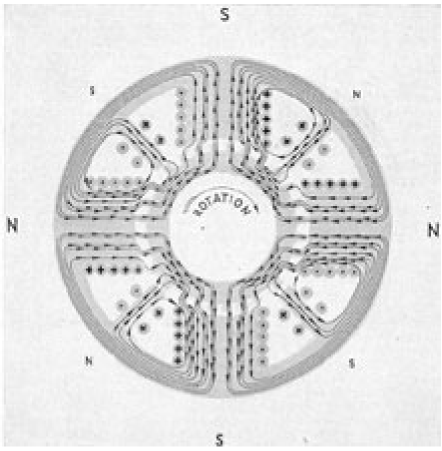


Figure 1-23. Effect of commutating field windings.

1E12. Compensating windings. To neutralize completely the effects of armature reaction, a second set of auxiliary field windings, known neutral plane will remain in fixed position throughout the entire range of load and speed of the machine, and, in the ease of a motor, in both directions of rotation. Good commutation is thus effected with the brushes located in a fixed position. Figure 1-24 shows the construction of these fields and windings.

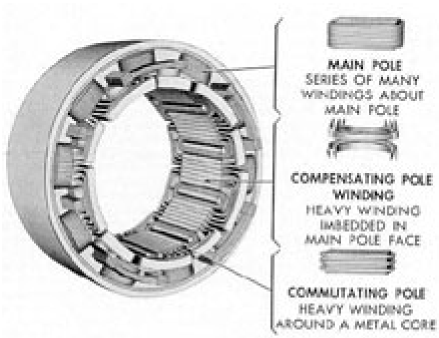


Figure 1-24. Construction of compensating windings.

1E13. Voltage control. The voltage produced by a generator is proportional to the strength of the magnetic field times the speed of rotation of the armature. The voltage of a shunt wound generator can be increased in any of the following ways:

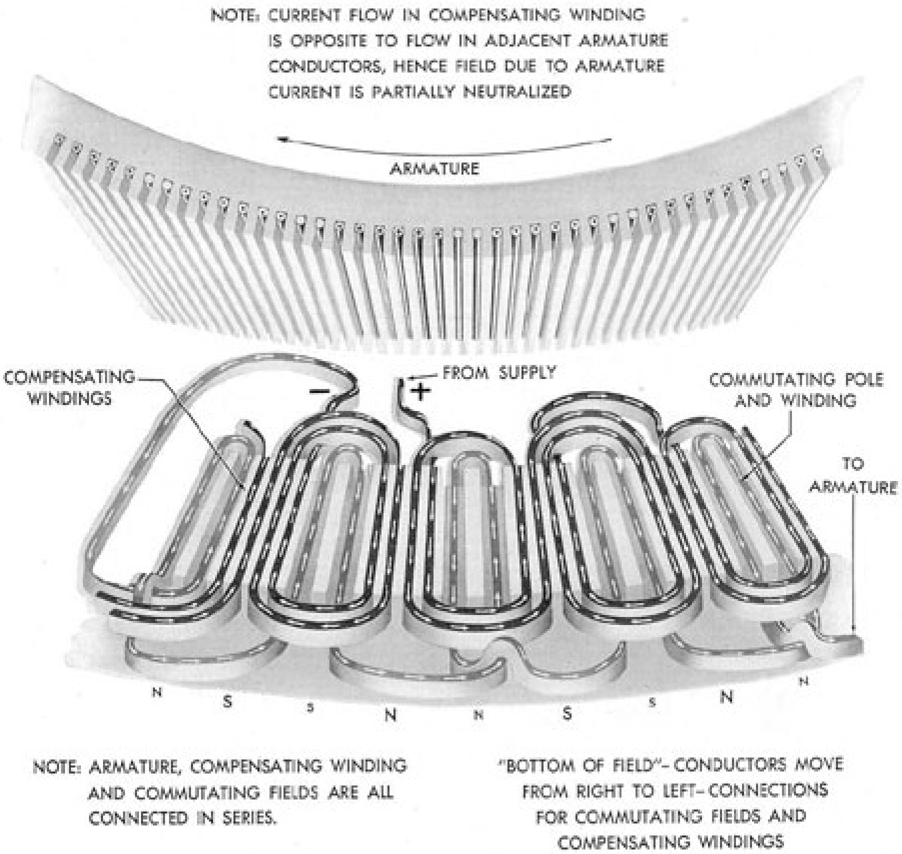


Figure 1-25. Currents in armature conductors, compensating windings, and commutating pole windings.

1. Keep the speed constant and increase the current through the field coils. This increases the magnetic field and the voltage.

2. Keep the field current and magnetic field constant and increase the speed of the engine that drives the generator.

3. Change both the field current and engine speed in such a way that the product of the magnetic field times the speed is increased.

Changing the engine speed and field current in the opposite direction causes the generator voltage to decrease.

F. DIRECT CURRENT MOTORS

1F1. Principles of operation. An electric motor is a machine for transforming electrical energy into mechanical energy. In this respect it is the reverse of a generator although it is based fundamentally upon the same general principles.

In construction, a direct current motor is the same as a direct current generator. When a motor is connected to a source of emf as, for example, a generator, the emf developed by the generator impels a current through the motor armature and field windings. Electromagnetic

reactions between the fields of the armature and the main field

magnetic field above the conductor but opposes it below

then cause the motor armature to rotate and pull its load.

The operation of a motor is based on the fact that a conductor carrying a current, when placed in a magnetic field, tends to move at a right angle to the field. Figure 1-26 (A) illustrates a magnetic field in which a conductor carrying no current is placed. In Figure 1-26 (B) the magnetic field has been removed and the conductor is shown carrying a current in a direction leading away from the reader. The current in the conductor has created a cylindrical magnetic field around it. The direction of this magnetic field may be determined by the right-hand rule: Grasp the wire in the right hand with the thumb pointing in the direction of the current. The fingers will then point in the direction of the magnetic field around the wire.

WARNING. Never grasp a real wire when it is hot. Put your fingers around an imaginary wire carrying current in the same direction.

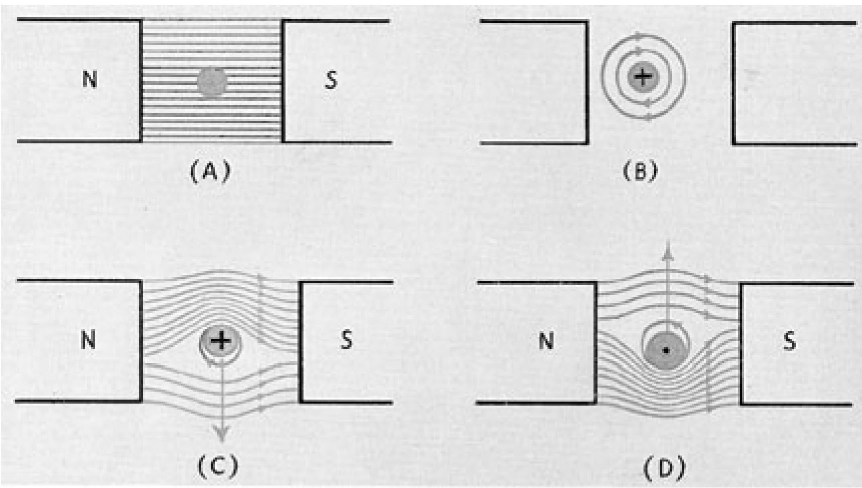


Figure 1-26. Force acting on a conductor carrying current in a magnetic field.

Figure 1-26 (C) shows the magnetic field obtained by combining the main magnetic the conductor. This action creates a crowding of the flux in the region above the conductor, and a reduction of the flux density in the region below the conductor. The crowding effect of the flux lines creates a force, comparable to elastic bands under tension and endeavoring to straighten out. This force exerts a downward pressure on the conductor; it is represented in the illustration by the arrow pointing downward.

When the current in the conductor flows in the opposite direction to that shown in Figure 1-26 (D), the crowding of the flux lines occurs below the conductor and tries therefore to force the conductor upward. This force is represented by the arrow pointing upward.

1F2. Counter electromotive force. As the motor armature rotates, an emf is induced in the armature exactly as in a generator. The emf induced in the armature is in a direction opposing, but never as great as, the emf impressed on the armature, causing it to rotate. Since this emf tends to cause a current in a direction opposite to

field and the magnetic field created by the current carrying conductor. The field created by the conductor acts in conjunction with the main that of the current causing the armature to turn, it is known as the counter, or back electromotive force. This counter emf is the

difference between the impressed voltage and the product of the armature current times the armature resistance.

1F3. Starting resistance. The effect of counter emf is to limit the current in a motor armature. The armature of a motor, as in a generator, is of very low resistance in order to reduce as much as possible current losses in the machine. When a motor at rest is suddenly connected to a source of current supply, an abnormally high current flows in the armature circuit because the counter emf is not present to oppose the applied voltage. For example, the armature resistance of a submarine main motor is only a few thousandths of an ohm. If a starting voltage of 250 volts were applied to the terminals, the current flowing the first instant would be enormous, resulting in serious damage to the motor and seriously overloading the generator supplying the current and the cables and contactors connecting them.

As soon as the motor starts to rotate, however, it generates a counter emf which increases as the motor gathers speed, thereby constantly reducing the armature current. To avoid this initial high inrush of current, a resistance is placed in series with the armature. This resistance is is cut out, allowing an increased current to flow again, thus supplying more torque, or turning tendency, which in turn speeds up the motor still more. This process continues until the motor terminals are connected directly across the supply line, the current by that time having been limited to a safe value by the counter emf. A motor should always be started with a strong field so that the counter emf may build up as rapidly as possible and also to provide the necessary torque.

1F4. Speed control. The most common method of controlling the speed of a motor is through variation of the shunt field strength. This method is based upon the fact that as the value of the flux is reduced, the motor speed is increased. The value of the flux is varied by placing a resistance (rheostat) in series with the shunt field circuit. Increasing the value of the resistance in series with the shunt field decreases the amount of current flowing through the field, and hence decreases the strength of the field. Any decrease in the strength of the field decreases the counter emf in the armature coils since the counter emf is dependent upon the number of lines of force cut by the coils on the armature. It is evident that with a weakened field, the lines of force cut are fewer and the counter emf produced is lower. This allows a greater current to

of such value that when the armature circuit is first closed, a current value about 1.5 times normal full load current flows. As the motor gathers speed, a portion of the resistance flow from the external voltage, which in turn causes an increase in the motor speed.

Sub Elec. Home Page Next chapter

2
MAIN GENERATORS AND MOTORS AND AUXILIARY GENERATOR

A. PROPULSION

2A1. Description. The propellers of a modern submarine are driven by four main motors (see Figure 2-1.) arranged in pairs to drive each propeller shaft through a reduction gear, or by two double armature main motors which are coupled directly to and operate in the speed range of the propellers.

Each gear unit used in a gear drive installation is a single reduction, double helical type designed to reduce the main motor speed of approximately 1300 revolutions per minute (rpm) to the propeller speed of 280 rpm.

Power for driving the main motors is obtained from one of two sources: the four main generators driven by the main diesel engines; or, for submerged operation, the main storage batteries.

A single main generator, or any combination of the four, may be employed for charging the main storage, batteries.

The auxiliary generator, driven by the auxiliary diesel engine, serves several purposes. It supplies current 1) for all auxiliary circuits, relieving the battery of the

Control of main propulsion machinery is accomplished through the main propulsion control equipment, or control cubicle, located in the maneuvering room.

Detailed descriptions and instructions for the care and maintenance of the various components and their related controls are given in the chapter dealing with each specific component.

2A2. Manufacturers of main propulsion equipment. Main motors, main generators, and auxiliary generators are produced for and furnished to the Navy by the following manufacturers: General Electric, Allis-Chalmers, Elliott, and Westinghouse.

Main control cubicles are manufactured by General Electric, Cutler-Hammer, and Westinghouse. Installations are usually paired as follows: General Electric motors, generators, and controls; Westinghouse motors, generators, and controls; Allis-Chalmers motors and generators and Cutler-Hammer controls; Elliott motors and generators and Westinghouse controls.

auxiliary load; 2) for charging the batteries at a low rate; and 3) for driving the main motors at slow speed through the main storage batteries.

Some of the differences that exist in electrical and structural design of equipment produced by these manufacturers are illustrated and described in this and the following chapters.

B. MAIN AND AUXILIARY GENERATORS

2B1. Description of main generators. The following terms describe the characteristics of main generators: two wire, direct current, separately excited, shunt wound, compensated multipolar, totally enclosed, and self ventilated. The armature shafts for generators used with General Motors engines are supported at each end on a bearing; those used with Fairbanks-Morse engines are so supported only at the commutator end. The bearings are force-lubricated by the oil supply from the main engine lubricating system.

The maximum speed of a main generator varies with the type of main engine. Maximum speed with a General Motors engine as a prime mover is 750 rpm; with a Fairbanks-Morse engine, 720 rpm. Direct flexible coupling to the engine is accomplished through the flanged end of the generator armature shaft.

With the exception of the cooling units on

Figure 2-1. GENERAL ARRANGEMENT OF MAIN PROPULSION EQUIPMENT, GEAR DRIVE AND DIRECT DRIVE.

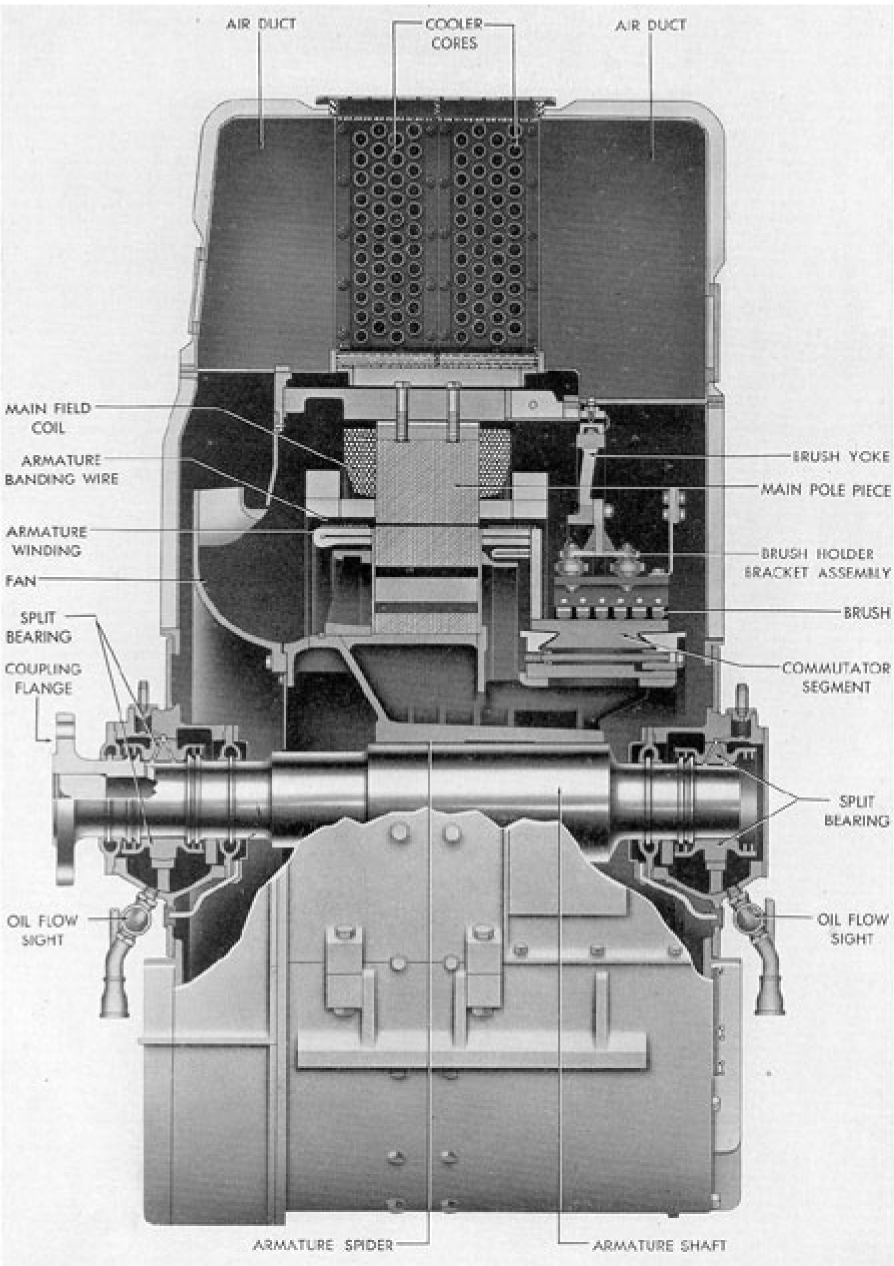


Figure 2-2. Cross-section of G.E. main generator.

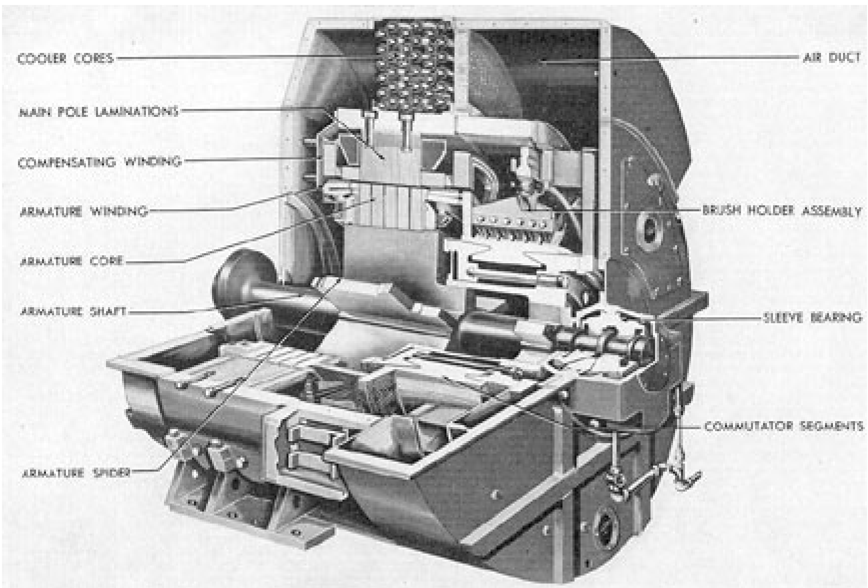


Figure 2-3. Cutaway of Westinghouse main generator.

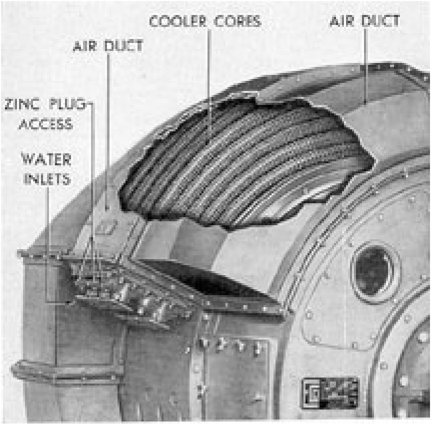


Figure 2-4. Cutaway of Elliott main generator cooling unit.

Figure 2-5. Cutaway of Allis-Chalmers main generator cooling unit.

Allis-Chalmers machines, the construction of all main and auxiliary generators is similar. The Main generators are rated at approximately 2650 amperes at 415 volts and 1100 kilowatts.

Detailed ratings and characteristics of the various machines are found in the individual manufacturer's instruction books.

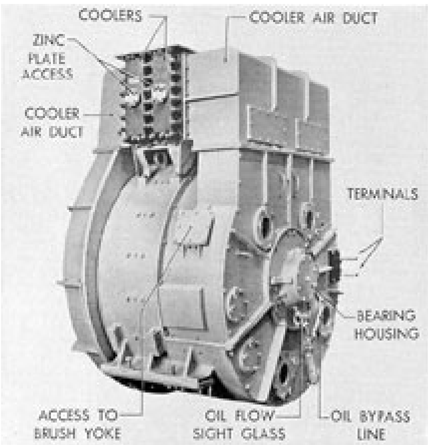


Figure 2-6. Commutator end view of G.E. main generator.

External views of various types of submarine propulsion generators are shown in Figures 2-2 through 2-10.

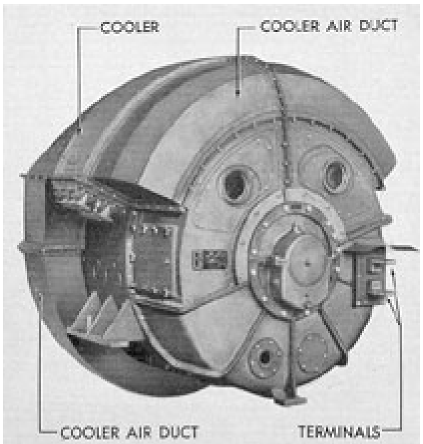


Figure 2-8. Commutator end view of Elliott main generator.

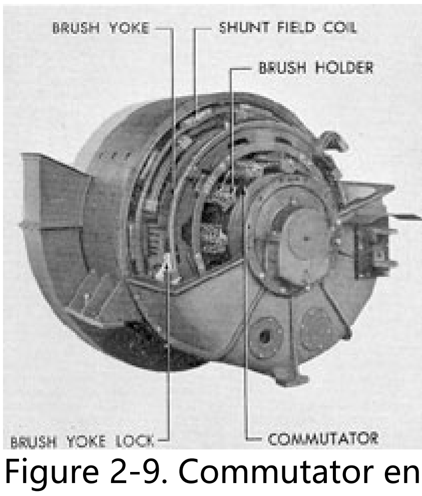


Figure 2-9. Commutator end view of Elliott main generator With front end bell removed.

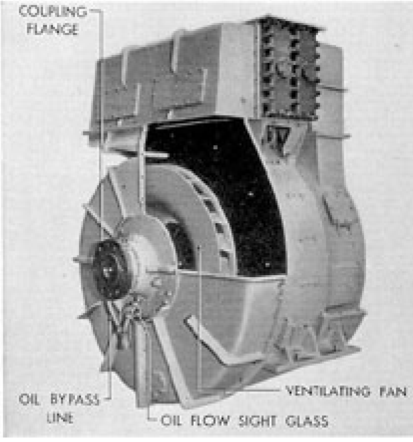


Figure 2-7. Coupling end view of G.E. main generator section cover removed.

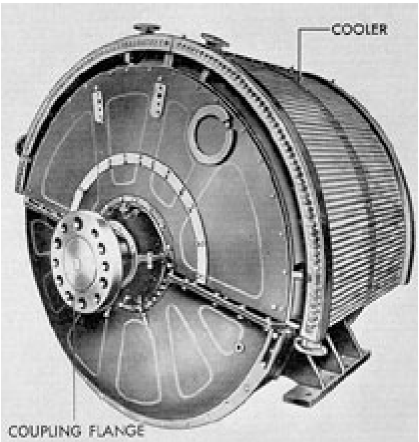


Figure 2-10. Coupling end view of Allis-Chalmers main generator.

2B2. Armature. The armature shaft is a single piece of forged steel. Coupling flanges, thrust collars, and oil deflectors are part of the shaft.

A spider for supporting the armature laminations is shrunk and keyed to the shaft. The core of the armature consists of magnetic steel punchings assembled in a group and secured to the spider by means of a shrink fit and keys. After the punchings are in position, a flange is pressed into place and held by circular keys.

mica, and held in position by V-shaped clamping rings. Mica is also used to insulate the segments from the clamping rings. The clamping rings are supported by through bolts or clamping studs, which, when tightened, hold the segments securely in position. The adjustment of these through bolts should never be changed.

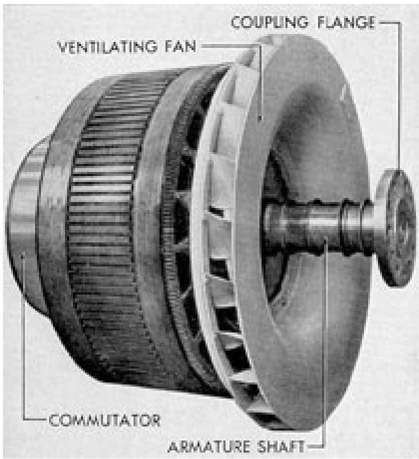


Figure 2-11, Coupling end view of G.E. main generator armature.

2B5. Brush rigging and brush holders. The brush rigging consists of a circular steel yoke to which the brush holder assemblies are attached. Some types of yokes have gear teeth cut around the outer periphery and meshed with a removable pinion for rotating

2B3. Armature windings. Armature windings consist of a number of single turn coils. These coils are placed in slots on the armature and held in place by slot wedges. The ends of the coils outside the slots are held by nonmagnetic steel banding wire. The windings are insulated from their supporting flanges by pieces of mica. An equalizer winding is provided in all submarine generators. It consists of connections between points of equal voltage in the armature circuit for balancing the current in the various armature circuits. It is usually located at the commutator end of the machine in a recess provided in the flanged portion of the spider. It is insulated from other parts by layers of mica.

2B4. Commutator. The commutator consists of copper segments insulated from each other by the rigging. Other types have holes drilled around the outer periphery into which a lever can be inserted to accomplish the same purpose.

Each brush holder is attached to a bracket which is secured to, but insulated from, the steel brush yoke. The brush holders contain brushes arranged two in a holder on each bracket. On General Electric and Elliott generators, one of the brushes in each holder runs with a leading angle and the other with a trailing angle. On Westinghouse and Allis-Chalmers generators, both brushes have a leading angle.

The complete brush rigging assembly is attached to the generator field frame and locked in position by clamps or studs. Access to the brush rigging lock is obtained by removing

inspection cover plates located on the side of the machine.

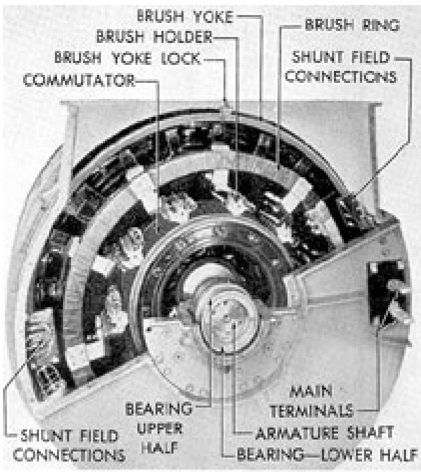


Figure 2-12. Commutator end of G.E. main generator, with cooler, end bell, and upper half of bearing housing removed.

compensating windings (see Section 1E12). Shims between the poles and the frame permit adjustment of the air gap.

The main field coils are wound around, but insulated from, the pole piece body. All coil leads for each half of the field are carried to terminal blocks located inside the machine. Any disabled coil may be cut out of the circuit at these terminal blocks.

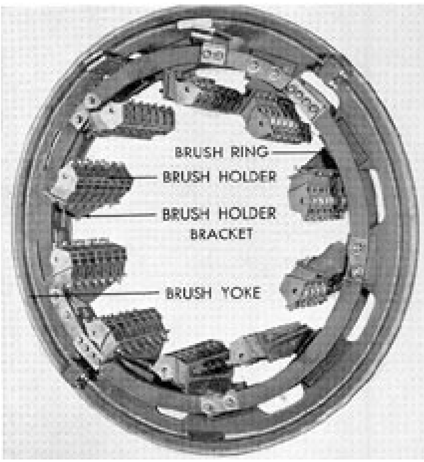


Figure 2-13. Main generator brush rigging.

2B6. Main field poles and coils. Each main field pole consists of a number of steel laminations riveted together and bolted to the frame. Each lamination has slots punched near the pole face to provide for insertion of the

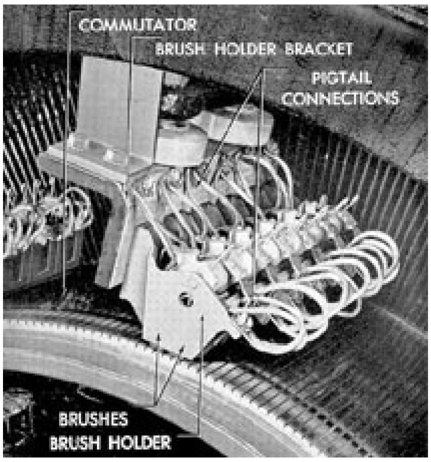


Figure 2-14. Brush holder and bracket.

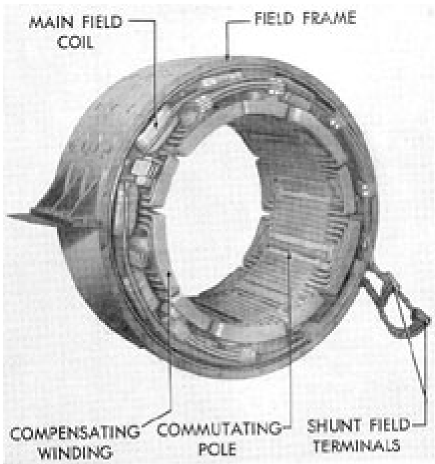


Figure 2-15. Main generator field frame and windings.

2B7. Commutating field poles and coils. The commutating field poles (see Section lEll) are made either of laminated or solid steel plate and are bolted to the frame. There are magnetic and nonmagnetic shims between the pole piece and the frame for adjusting the air gap and strength of the commutating fields. The coil consists of several turns of solid copper bus bar fastened to the pole piece by means of insulated steel studs.

2B8. Compensating winding. The compensating winding (see Section lE12) consists of copper bars inserted in slots in the main

the commutator end are lined with soft metal to take the thrust load.

Escape of oil from the housing is prevented by deflector rings on the armature shaft and by oil seals in each inner half of the bearing housing.

An air chamber around the shaft at the inside end of the bearing housing is vented by pipes to the outside of the machine. This prevents the formation of a vacuum around the shaft and provides a drain for any possible oil leakage before it reaches the interior of the machine.

pole pieces. The winding elements are insulated from the pole by mica and joined by copper bars bolted in place.

The bearing is drained through a pipe equipped with an oil flow sight. To prevent an excessive flow of oil from reaching the bearing,

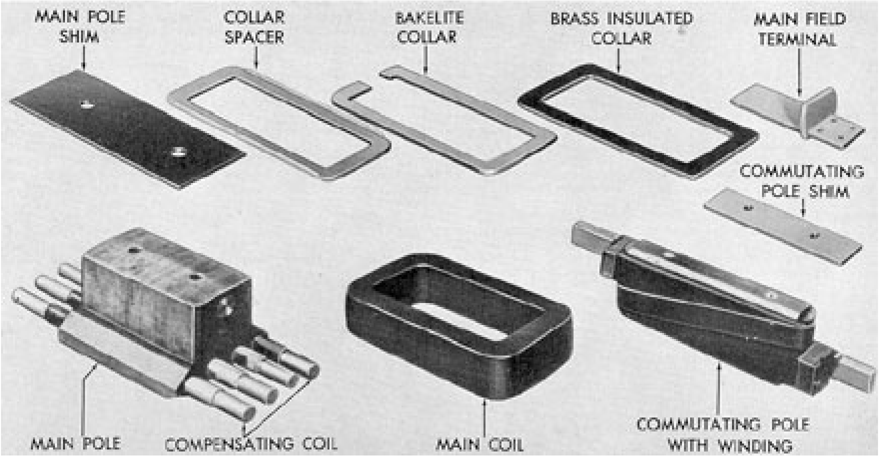


Figure 2-16. Miscellaneous field parts, Allis-Chalmers.

2B9. Terminals. The armature terminals are brought out through a terminal board. These terminals are silver plated to obtain low contact resistance.

2B10. Bearing and bearing lubrication. The bearing consists of a split shell, lined with soft metal, usually babbitt. It is carried in a split housing which is in turn bolted to the frame of the machine. The two halves of the bearing shell are accurately aligned by two dowel pins, one on each side. The ends of the bearing shells at

and also to allow the use of openings in the feed line of not less than 3/16-in. diameter, some of the oil is bypassed around the bearing. Pressure at the inlet to the bypass chamber should be 10 to 15 pounds per square inch.

In order to remove the upper half of the bearing housing, it is necessary on some machines to remove an adapter plate first, thus providing sufficient clearance for lifting the bearing housing over the bearing. Lifting jackscrews are provided, which, when turned, lift

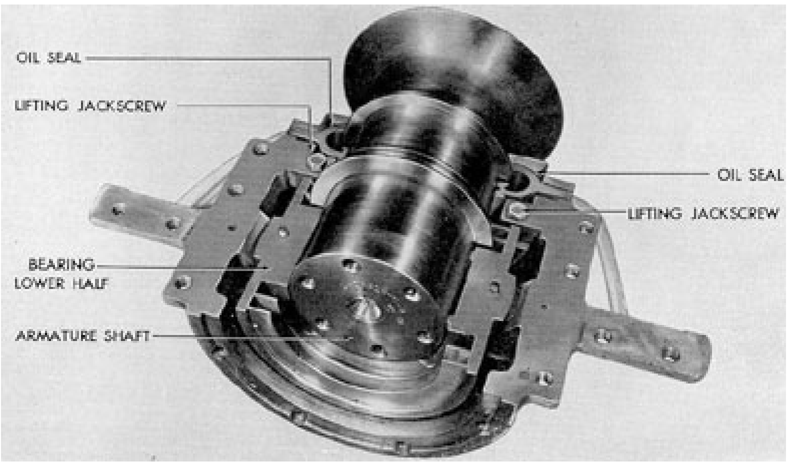


Figure 2-17. Lower half of main generator bearing installed.

the shaft slightly and permit rotation of the lower half of the bearing to the top of the shaft for removal (see Section 7A12). Serious casualties have been caused by failure of repair personnel to lower the jack after replacing a bearing.

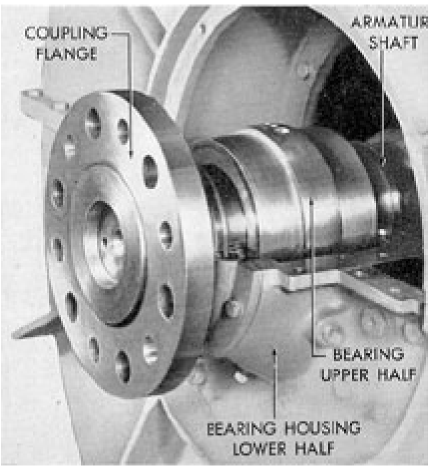


Figure 2-18. Main generator bearing, coupling end.

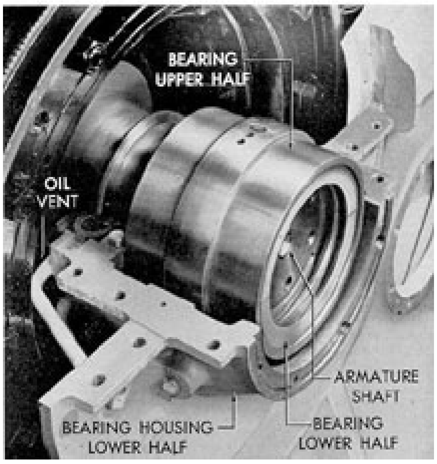


Figure 2-19. Main generator bearing, commutator end.

2B11. Cooling systems. The cooling systems of all the various machines operate on the same principle. The hot air is cooled by forcing it through water-cooled cores, The Allis-Chalmers machines, however, do not employ the ductwork

used on the other makes of machines (see Figure 2-5). The cooling unit on these generators fits the contour of the machine and is made in two sections, each half-section covering one fourth of the outer surface of the generator. Water tubes are set in grooves on the outer surface of the shell to absorb the heat from the circulating air.

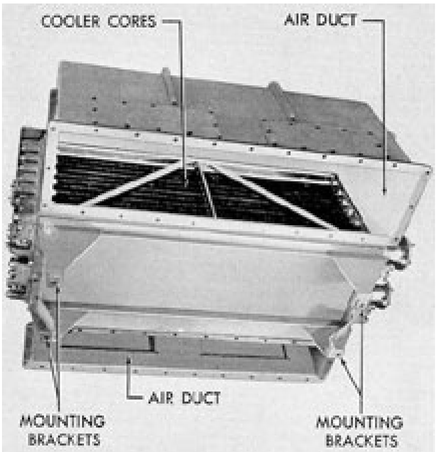


Figure 2-20. Bottom view of G.E. main generator cooling unit.

The other makes of machines have the water tubes mounted in cores, similar to an automobile radiator. This assembly is located in the air ducts of the cooling system through which the air passes.

Circulation of air is effected by the ventilating fan attached to the armature shafts. Air is delivered from the cooler into

the commutator end housing. It is then drawn through the field coils and through the commutator ends, under the commutator into the armature, and then through ventilating ducts in the armature core. On Westinghouse generators the fan is located on the commutator end and the air flow is thus reversed.

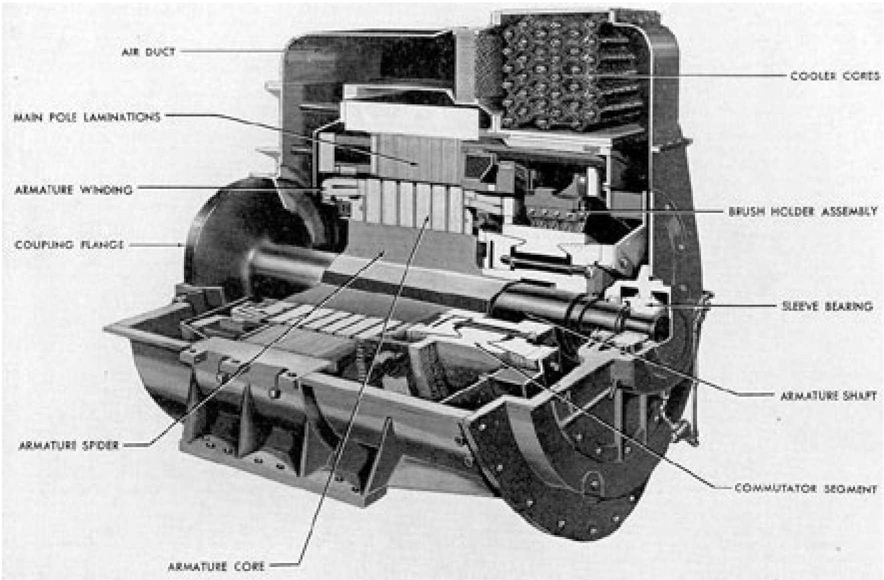


Figure 2-21. Cutaway of Westinghouse auxiliary generator.

The coolers are designed to deliver air at 104 degrees F to the windings. The air entering the coolers may vary in temperature, depending on the type of machine. The manufacturer's instruction books give the maximum allowable temperatures of the air from the windings.

2B12. Description of the auxiliary generator. The 300-kw direct current auxiliary generator Is a two-wire, compensated, differential compound machine. The generator is self-excited, but the switching is arranged so that separate excitation may be obtained from the battery. The the auxiliary and main generators are identical.

The rating and classification of the auxiliary generators can be found in the manufacturer's instruction book furnished with the equipment. The various makes and some of the principal components are illustrated in Figures 2-21 through 2-30.

machines can produce 300 kw at 1200 rpm at any voltage from 260 volts to 345 volts, and 150 kw at 600 rpm at 260 volts.

The generator is connected to the auxiliary Diesel engine through a semirigid coupling. The commutator end of the armature shaft is supported on a sleeve bearing which is force-lubricated from the engine lubricating system. The opposite end of the shaft is carried by the engine bearing. The generator armature thrust is taken by thrust collars on the shaft and thrust faces on the ends of the sleeve bearing.

In construction, auxiliary generators differ only in minor detail from the main generators. They are produced by the same manufacturers and, with the exception of differences in size, weight, and number of some of the components,

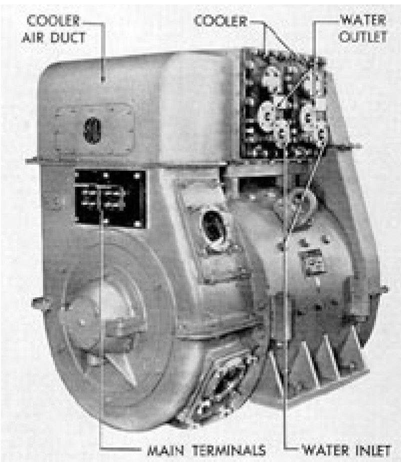


Figure 2-22. Right front view of G.E. auxiliary generator.

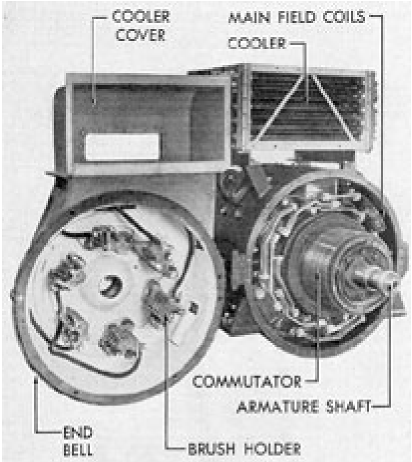


Figure 2-23. Front view of G.E. auxiliary generator, end shield and cooler cover removed.

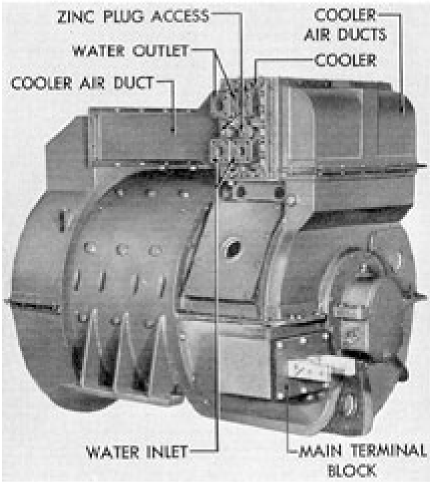


Figure 2-24. Commutator end view of Elliot auxiliary generator.

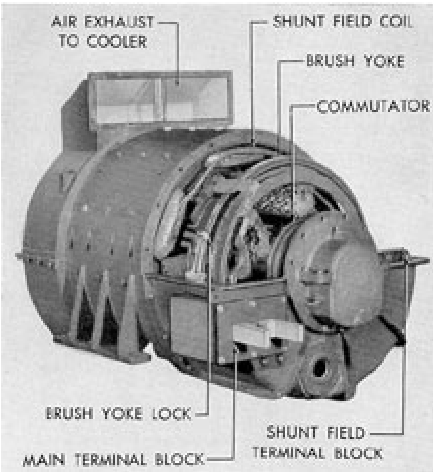


Figure 2-25. Elliott auxiliary generator, end bell and cooler removed.

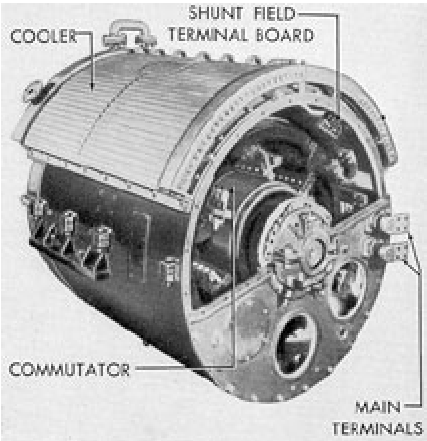


Figure 2-26. Commutator end view of Allis-Chalmers auxiliary generator, end cover removed.

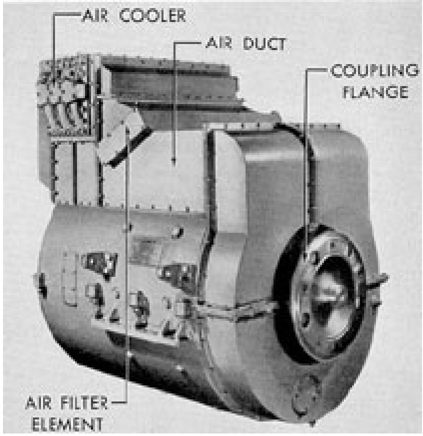


Figure 2-27. Later type Allis-Chalmers auxiliary generator.

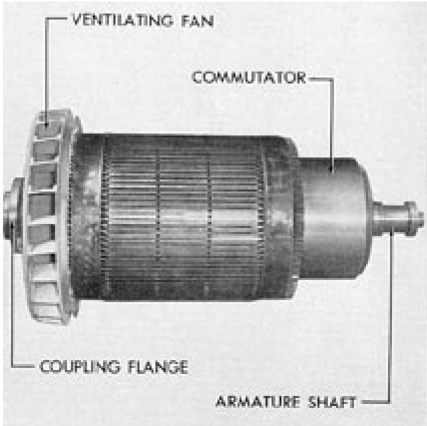


Figure 2-28. Armature for G.E. auxiliary generator.

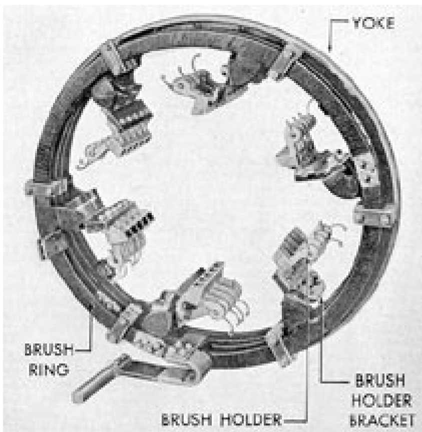


Figure 2-29. Allis-Chalmers auxiliary generator brush rigging.

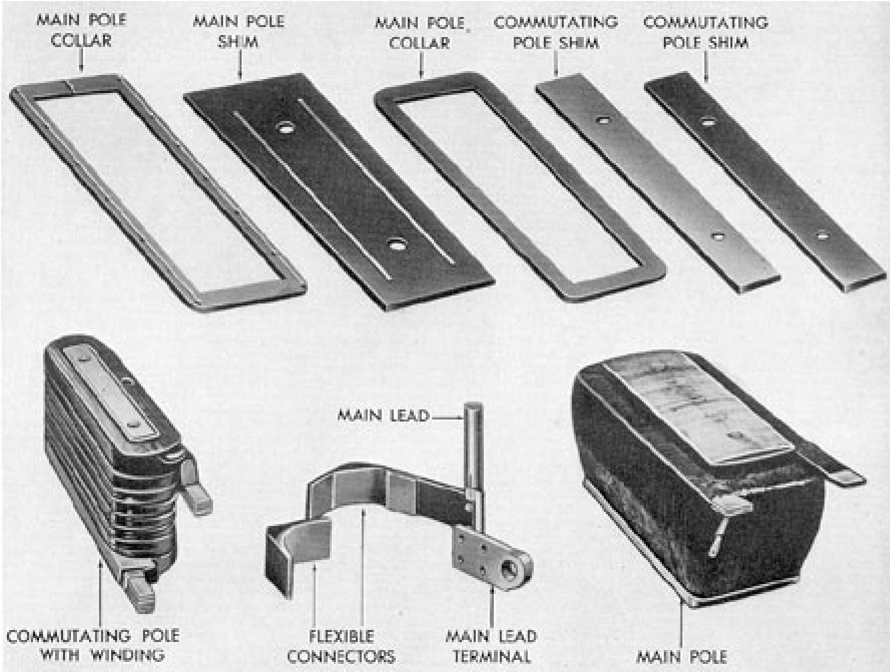


Figure 2-30. Miscellaneous field parts, Allis-Chalmers auxiliary generator.

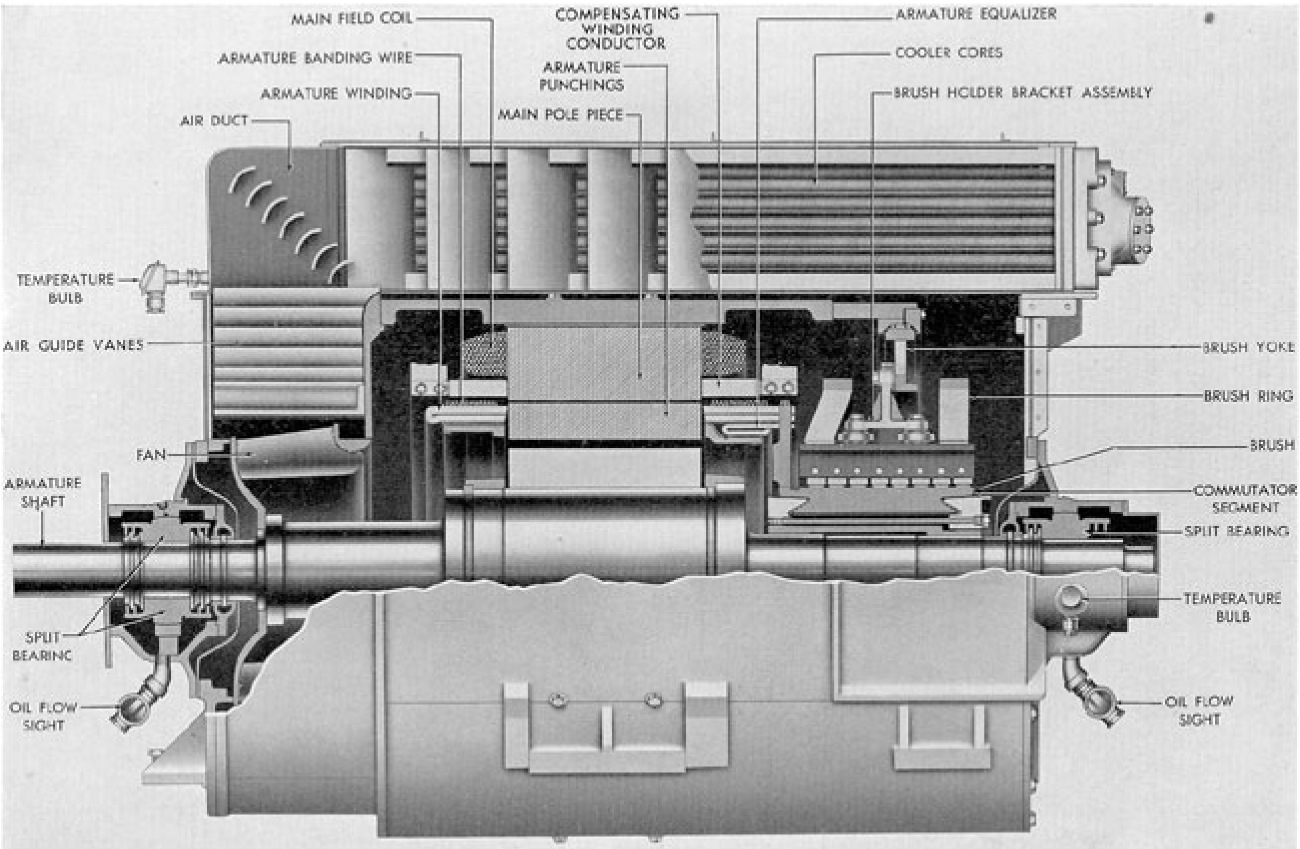


Figure 2-31. Cross section of G.E. main motor.

C. MAIN MOTORS

2C1. Description of geared main motors. The geared type by varying the motor shunt field or by connecting the motors in

main motors are of the two-wire, d.c., compound type with shunt, series, commutating, and compensating field windings. Separate excitation for the shunt field is provided by the excitation bus which receives power from either battery.

The motors are totally enclosed, watertight below the field frame split and waterproof above. Cooling is accomplished by a fan which is attached to the armature shaft and circulates the air through cores cooled by circulating water.

Each end of the armature shaft is supported on a split sleeve bearing. The bearings are lubricated from the oil supply in the reduction gear units.

Various combinations of armatures in series or in parallel, including the coupling of all four motors in series for dead slow operation, may be obtained, for either surface or submerged operation, through the main control cubicle.

For surface operation, motor speed control is accomplished by controlling the generator speed and shunt field, thus varying the voltage supplied. When submerged, speed is controlled different combinations of series and parallel. Reverse operation is accomplished by reversing the direction of the flow of current in the motor armature circuit.

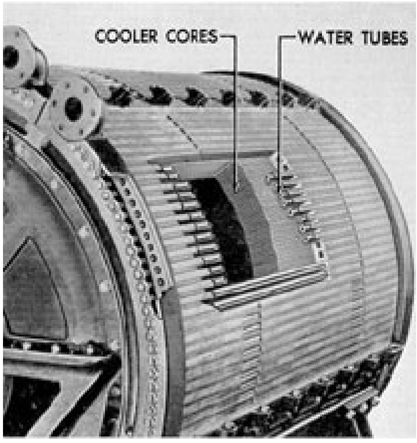


Figure 2-33. Cutaway of Allis-Chalmers main motor cooler section.

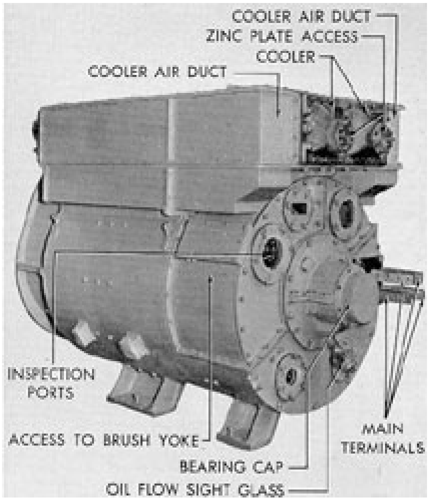


Figure 2-34. Commutator end view of G.E. main motor.

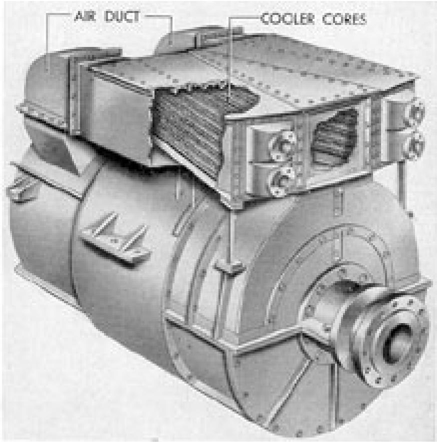


Figure 2-32. Cutaway of Elliott main motor cooler section.

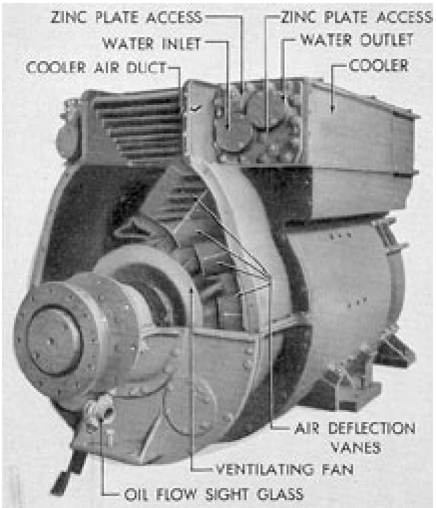


Figure 2-35. Coupling end view of G.E. main motor, flat cover plate and air duct cover removed.

Main motors used in a gear drive installation are classed as high-speed motors and each is rated for continuous duty at approximately 1370 hp, 415 volts, 2600 amperes, and 1300 rpm.

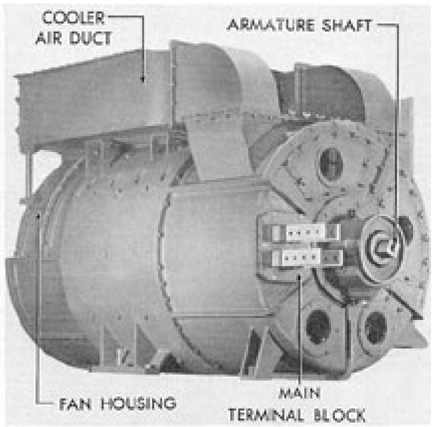


Figure 2-36. Commutator end view of Elliott main motor.

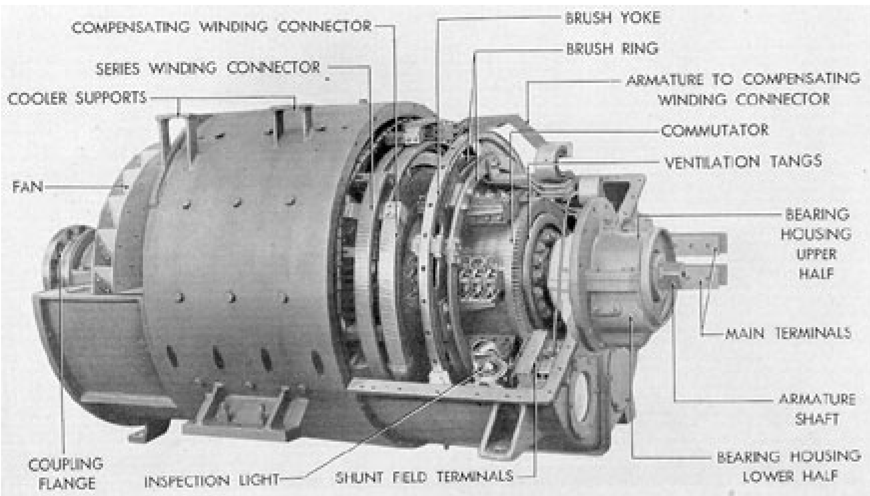


Figure 2-37. Elliott main motor with end bells removed.

2C2. Commutator, armature, armature windings, brush rigging, brush holders, field frame, and windings. Figures 2-38 through 2-42 illustrate these parts. They are practically identical in construction with the corresponding parts of a main generator. For their description, see Section 2B.

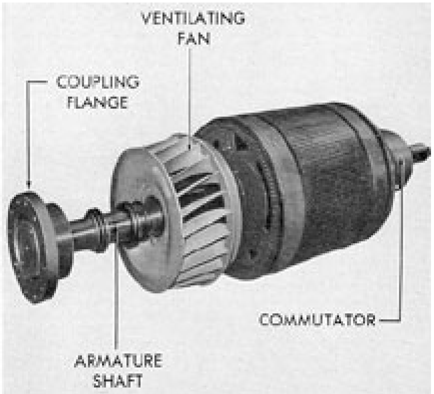


Figure 2-38. Coupling end view of G.E. main motor armature.

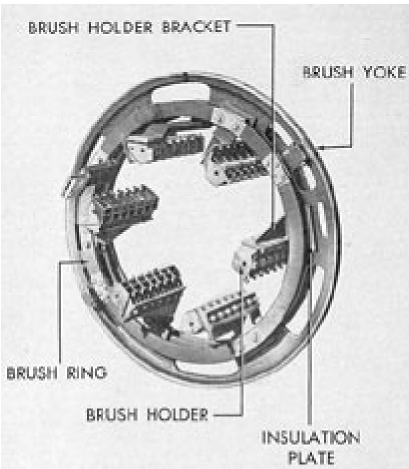


Figure 2-39. Main motor brush rigging.

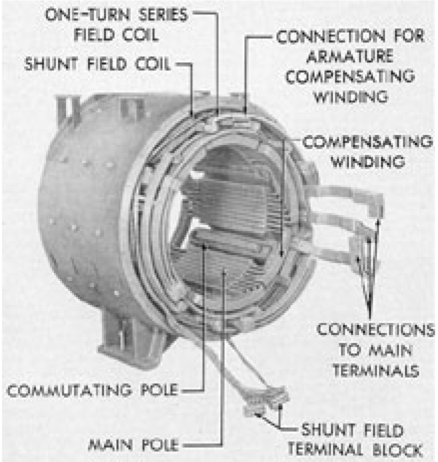


Figure 2-40. Main motor field frame and windings.

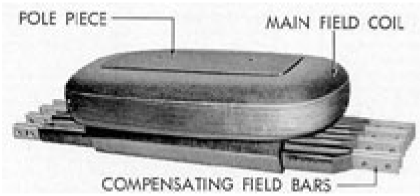


Figure 2-41. Main coil on pole piece with compensating field bars.

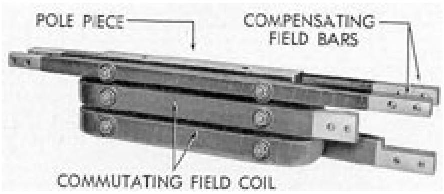


Figure 2-42. Commutating field toil on pole piece with compensating field bars.

2C3. Bearings. As in the main generators, the armature shaft of a main motor is supported on a split sleeve with a spherical or cylindrical seated bearing at each end. The two halves of the bearing are held together between two halves of the bearing housings which are clamped together and bolted to the bearing brackets. End clearance at the commutator end is large enough to make certain that the thrust

load will be taken by the coupling end bearing only. Each bearing is sealed against oil leakage by deflector rings and oil seals. The bearing temperatures are measured by Brown resistance temperature units, the detectors of the units being located in the lower halves of the bearings. The maximum safe operating temperature of the bearings is 180 degrees F.

2C4. Lubrication. Oil under pressure is supplied to the motor bearings by a gear-driven lubricating oil pump which is attached to the reduction gear units of each pair of motors. However, when the propeller shaft speed is below 38 rpm, a standby pump which supplies sufficient oil pressure both for reduction gears and main motor bearings is placed in operation. Oil catching grooves and return drains in the housing prevent leakage of oil along the shaft into the windings. An air chamber between the bearing and the interior of the motor serves to prevent the formation of a vacuum around the shaft and permits drainage of any possible oil leakage before it reaches the interior of the motor. A safety overflow is provided in the housing oil reservoir to prevent possible flooding of the winding if the drain should become clogged. After passing through the bearing, the oil passes out of the housing through a sight flow and returns to the lubricating oil sump. When the flow of oil at the sight flow glass appears to be appreciably reduced or, if the oil pressure falls below 5 psi, the standby pump must be placed in reduction gears have been replaced by two 2700-hp double armature motors, directly connected to the propeller shafts, one to the starboard, the other to the port shaft.

The motors are of the two-wire, d.c., compound, compensated type with shunt and series field windings and commutating poles. Separate excitation for shunt fields is provided by the excitation bus which receives power directly from the battery buses in the control cubicle. The motors are totally enclosed and a water tube air cooler is mounted crosswise over the motor frame. Mechanical air filters are located in the air ducts between the coolers and vent blower. A separate motor-driven fan circulates the cooling air. When the motors are operating in the SLOW position, neither cooling air nor circulating water is required. The motor for the ventilation fans normally is connected across the terminals of one of the propulsion motor armatures. When the bus selector lever is in the SLOW position, this connection is opened.

If at any time it becomes necessary to disconnect the propulsion motor armature to which the vent blower is normally connected, and still operate the other propulsion motor armature, the vent motor connections can be shifted to the armature intended for operation by means of connector links provided in the vent motor leads in the control cubicle.

The motor frame is split at an angle of approximately 11 degrees from the horizontal centerline to permit easy removal of the

operation. The standby system is also used to force lubricant to the bearings before starting the motors after a shutdown period.

2C5. Cooling systems. The main motor cooling units are similar to the main generator units with one exception. The Allis-Chalmers cooling units on the main motor are constructed in three sections and cover approximately 90 percent of the outer surface of the motor frame. The remaining surface is covered with a dummy section to secure the necessary clearance for the motor arrangement in the motor room. The arrangement is such that each motor has its cooler sections placed on different portions of its outer surface.

2C6. Description of double armature propulsion motor. a. General. On the latest classes of submarines, main motors and armature. The motor is watertight below this joint and waterproof above.

The armature is mounted on a hollow forged steel shaft which is flanged at the after end for coupling to the propeller shaft. Each end of the shaft has a bearing journal for a force-lubricated, split sleeve bearing mounted in a pedestal separate from the frame. In addition to the radial bearing, the forward end of the shaft is fitted with a collar for a Kingsbury thrust bearing which takes the propeller and motor thrust load.

To secure proper compensating field strength over the entire operating range, the compensating winding of each motor is shunted by a permanent resistor which is adjusted to give good commutation over the entire range.

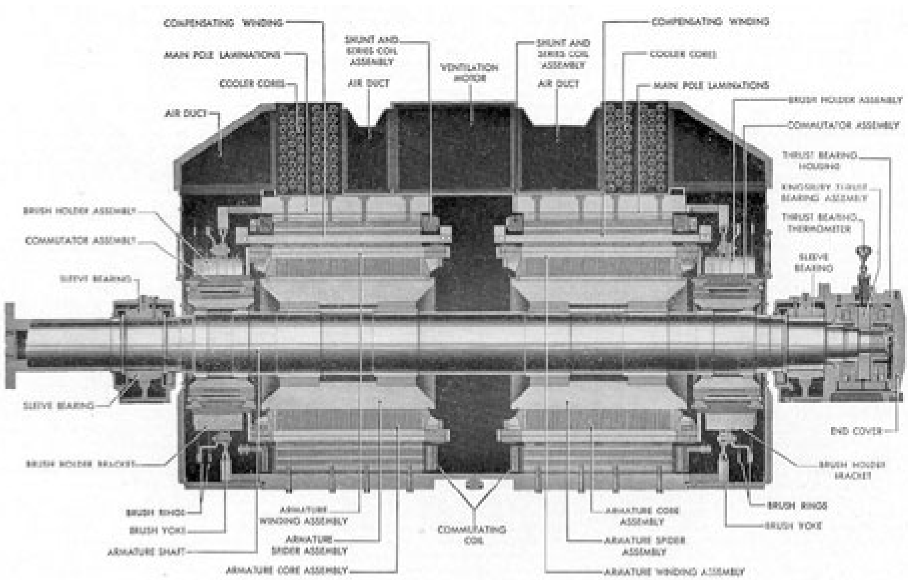


Figure 2-43. Cross section of Elliott double armature propulsion motor.

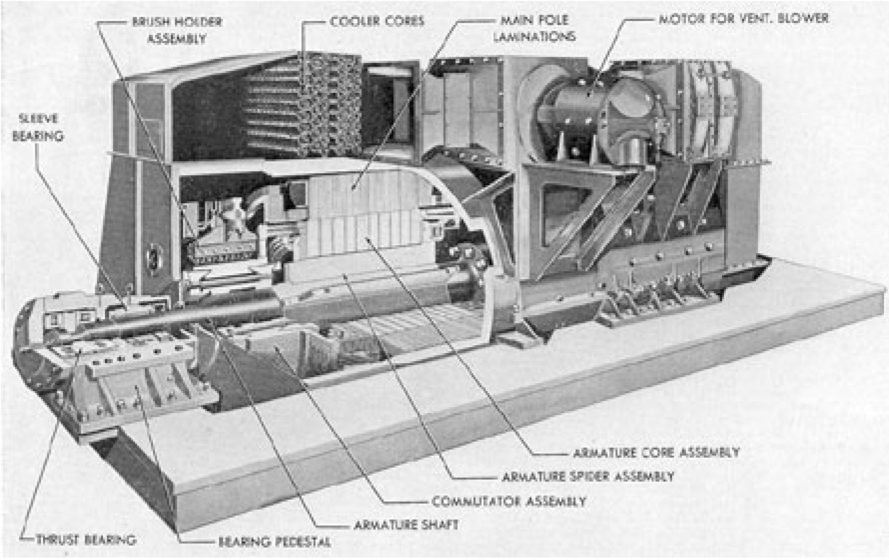


Figure 2-44. Cutaway of Westinghouse double armature propulsion motor.

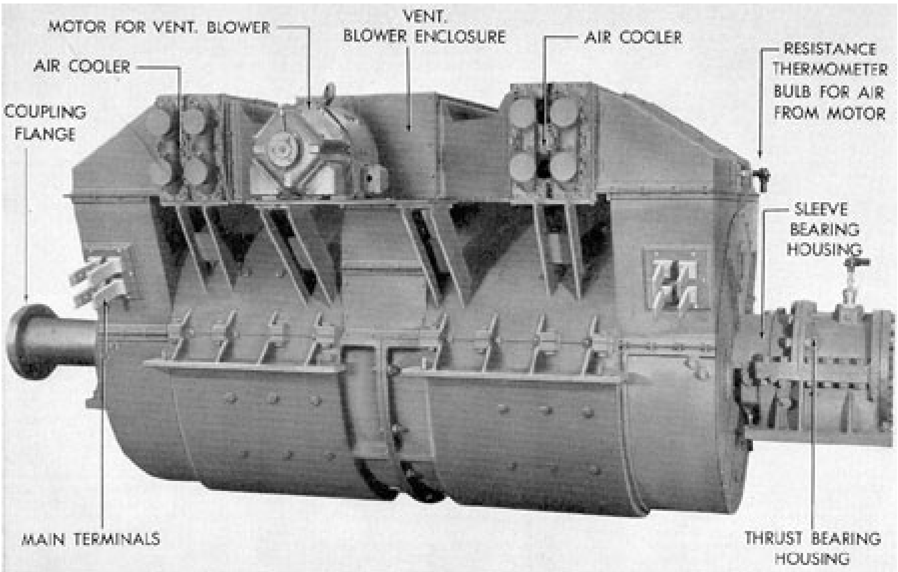


Figure 2-45. Double armature propulsion motor.

b. Operation. For surface operation, using the various combinations of armatures and taking power from the main generators, the motors develop from 20 hp to 2700 hp per propeller shaft at speeds ranging from approximately 67 rpm to 282 rpm.

For submerged operation, using various combinations of armatures and taking power from the batteries, the motors develop power ranging from 30 hp to 1719 hp per propeller shaft drain into the bottom of the end enclosures or center section and may be drained off from there with a hand pump. Steel brackets are bolted and doweled to the frame sections for support of the brush rigging. Removable plates provide access to the connections.

d. Bearings. The radial bearing sleeves are carried in split cast steel pedestals. These are bolted to the motor bedplate which is welded to the hull. The caps of the bearing pedestals are held in position by fitted studs.

and give a speed range from 38 rpm to 219 rpm.

c. Motor frame. The motor frame is constructed in two halves which are doweled together. Jackscrews in the supporting feet assist in shimming and properly aligning the frame. The frame and enclosures are watertight below the frame split and waterproof above. Any condensate or liquid from other sources that may find its way into the interior of the motor will

Bearing sleeves are made of cast steel lined with babbitt. They are machined to fit the spherical seat in the bearing pedestal and are secured against rotation by a dowel pin in the pedestal cap. The babbitt on the sides of the sleeves is cut away slightly to allow proper distribution of oil. Grooves through the sides of the sleeves at the horizontal split permit a circulation of oil in addition to that which passes under

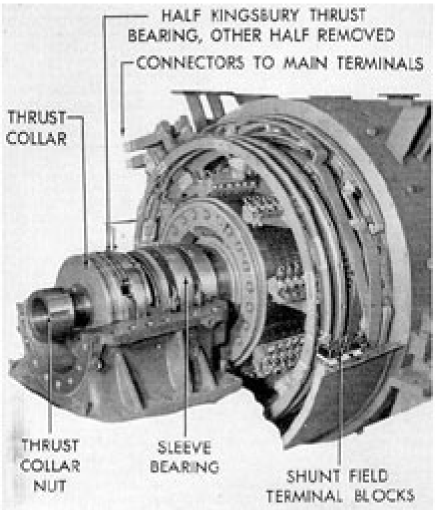


Figure 2-46. Double armature propulsion motor with enclosures removed.

the shaft. This extra flow of oil passing over the shaft journal carries away heat and also tends to prevent collection of sludge in the bearings.

A jacking beam is provided in the lower housing to support the shaft while removing bearing sleeves. The bearing pedestals and sleeves are drilled to permit the use of a depth gage for measuring bearing wear. A bridge gage may also be used for measuring bearing wear or to locate properly a new bearing shell.

The Kingsbury thrust bearing on the forward end of the shaft takes the thrust load of the propeller and motor in both ahead and astern directions. The bearing consists of a rotating collar keyed to the shaft, and stationary shoes with load-equalizing supports or leveling plates which allow for slight misalignment.

e. Lubrication. Oil is supplied to the bearings by a separate motor-driven lubricating oil pump for each shaft. Oil-catching grooves and felt wipers in the housing prevent leakage of oil along the shaft. After passing through the bearing, the oil passes out of the

housing through a sight flow and returns to the sump tank.

A resistance type temperature detector for indicating bearing temperature is located in the lower half of each radial bearing and in the discharge oil from the Kingsbury thrust bearing.

f. Armature shaft. Except in Westinghouse motors, the armature shaft is a one-piece

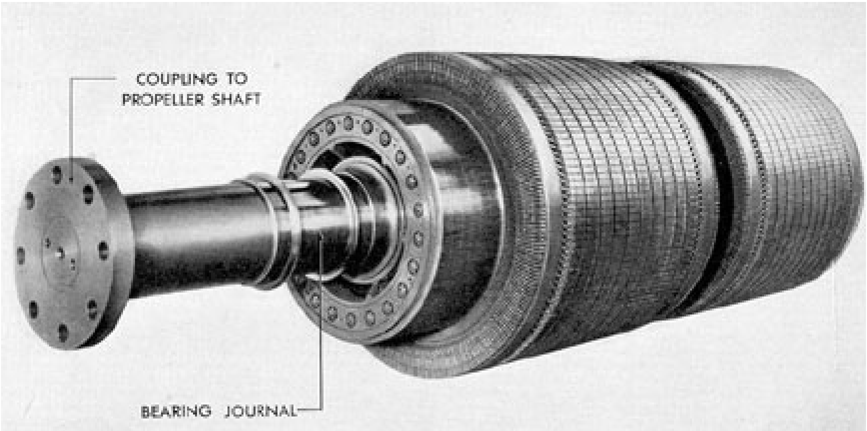


Figure 2-47. Propulsion motor double armature, coupling end.

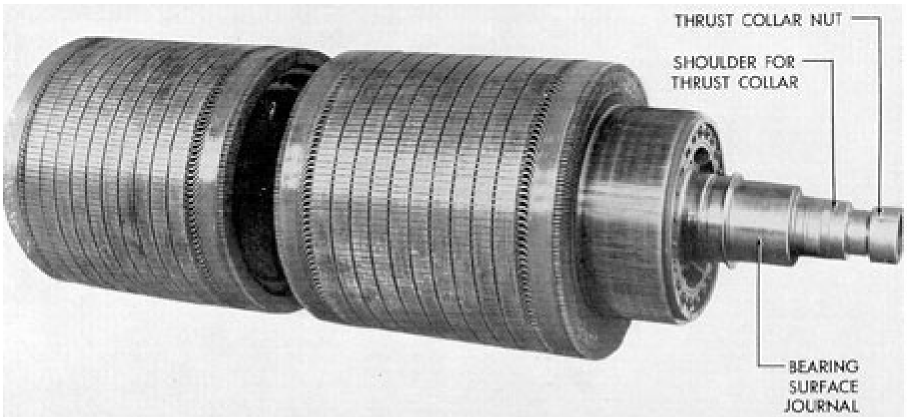


Figure 2-48. Propulsion motor double armature, thrust bearing end.

steel forging machined to proper fit for support of two armatures and their commutators. Westinghouse motors have two-piece shafts coupled together in the center. Three oil throwing collars are machined on the shaft one on each side of the bearing journal at the coupling end, and

commutators, brush rigging, brush holders, and field windings. With the exception of minor details, the construction of these components is similar to that of the corresponding parts of a high-speed main motor or generator. The field frame and windings are illustrated in Figure 2-49. For specific details refer to the

one on the forward end of the shaft.

g. Armature core, armature winding,

manufacturer's instruction book furnished with the equipment.

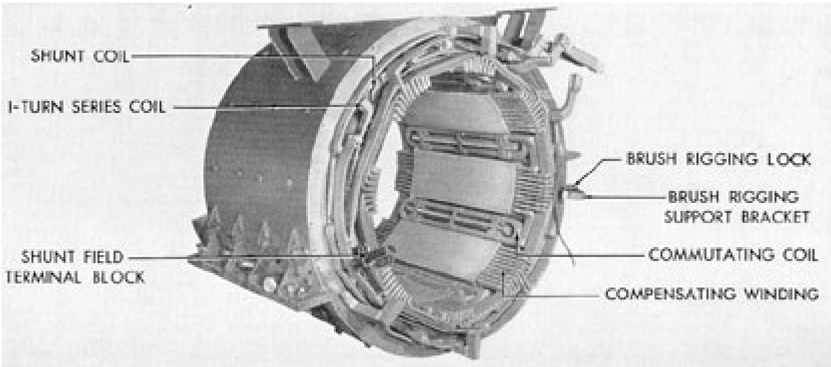


Figure 2-49. Double armature propulsion motor field frame and windings.

D. CABLES

2D1. General. Each of the various types of electrical cables used on submarines has a certain number of conductors and a type of insulation designed for a specific application. Each type and size has a definite rating with respect the maximum operating voltage for which it is designed, the maximum load in amperes to

Cables are identified as to type by letters followed by a number that indicates for power cables the size in circular mils. For interior communication and fire control cables, the number indicates the number of conductors or pairs of conductors. For example, the designation SHFL-800 identifies a single conductor,

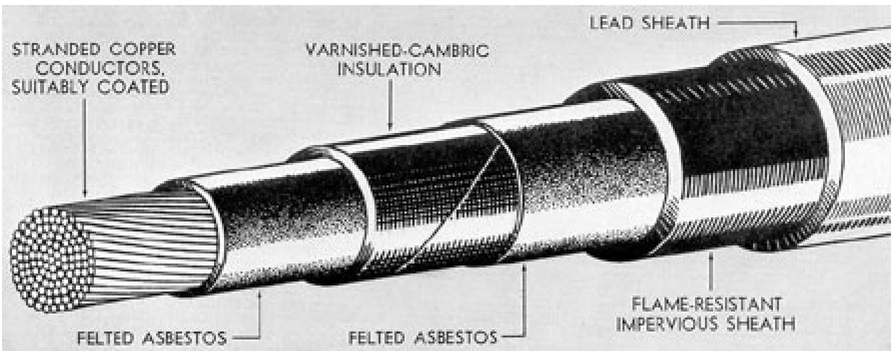


Figure 2-50. Type SHFL single conductor heat and flame resistant leaded cable.

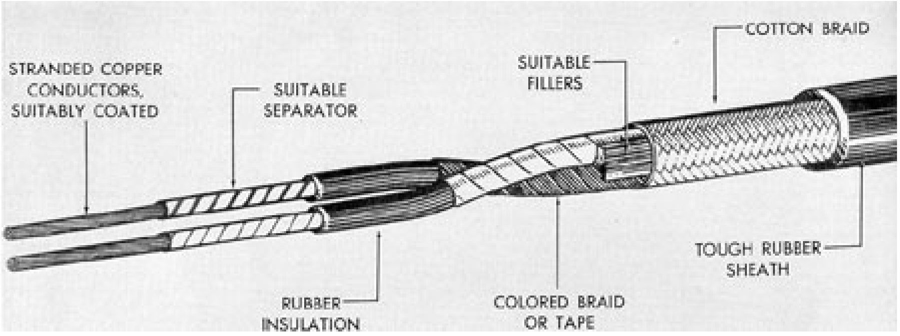


Figure 2-51. Type DCP double conductor portable cable.

be carried under specified conditions, the maximum extremes of temperature to which the cable would normally be exposed, and its relative resistance to moisture or flame. The construction of three types of cables is illustrated in Figures 2-50, 2-51, and 2-52. The labeled parts will be helpful in understanding the inner composition of the various cables illustrated.

heat and flame resistant, leaded cable with an area of approximately 800,000 circular mils. An MHFA-10 cable is a multiple conductor, heat and flame resistant, armored cable of 10 conductors.

To facilitate tracing of cable for purposes of maintenance and replacement, metal tags stamped with a circuit marking are attached

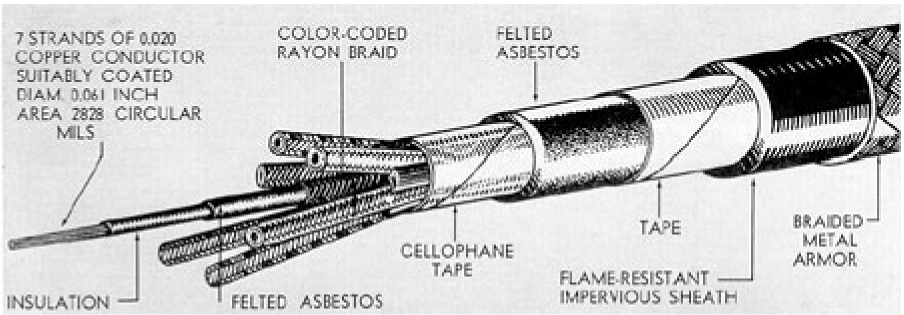


Figure 2-52. Type MHFA multiple conductor beat and flame resistant armored cable.

to the cables (see "How to Read a Cable Tag," Section 20D). For specific information on the routing of a cable run, consult the wiring deck plan applying to the specific installation.

2D2. Main power cables. The following is a list of the types and numbers of cables and their approximate length as used on a few of the main power circuits. This description is of a typical installation. Considerable variation will be found in the various classes of submarines.

generator cables are approximately 50 ft long. Each of the 8 No. 3 and No. 4 generator cables are approximately 15 ft long. Shunt field, ammeter, and voltmeter cables are type DHFA-4, DHFA-9, and DHFA-3 respectively.

5. Main motor armature and series field, positive and negative. The No. 3 and No. 4 main motor circuits employ 16 type SHFL-800 cables for each motor, 4 cables for each armature leg and 4 cables for each series field leg. Each cable is approximately 15 ft long. All main

1. Forward battery to maneuvering room. This circuit employs 12 type SHFL-800 cables, each of which is approximately 150 ft long. In addition, there is 1 type DHFA-9 ammeter lead, 170 ft long.

2. Auxiliary power distribution switchboard; circuit run from forward battery to control room. This circuit employs 4 type SHFL-650 cables, each of which is 35 ft long, and 1 type SHFA-75 neutral lead of the same length.

3. After battery to maneuvering room. This circuit employs 8 type SHFL-800 cables, each of which is approximately 85 ft long, and 1 type DHFA-9 ammeter lead, approximately 110 ft long.

4. Main generators to maneuvering room. These circuits employ 8 type SHFL-1000 cables, 4 cables for the positive and 4 for the negative legs. The No. 1 and No. 2 generator cables run from the forward engine room to the maneuvering room; the No. 3 and No. 4 generator cables run from the after engine room to the maneuvering room. Each of the 8 No. 1 and No. 2 motor shunt field leads are of type DHFA-4 cable, approximately 20 ft long. No. 1 and No. 2 main motors are similarly connected but on some installations bus bars are used instead of cables. Each bar or cable is approximately 4 ft long.

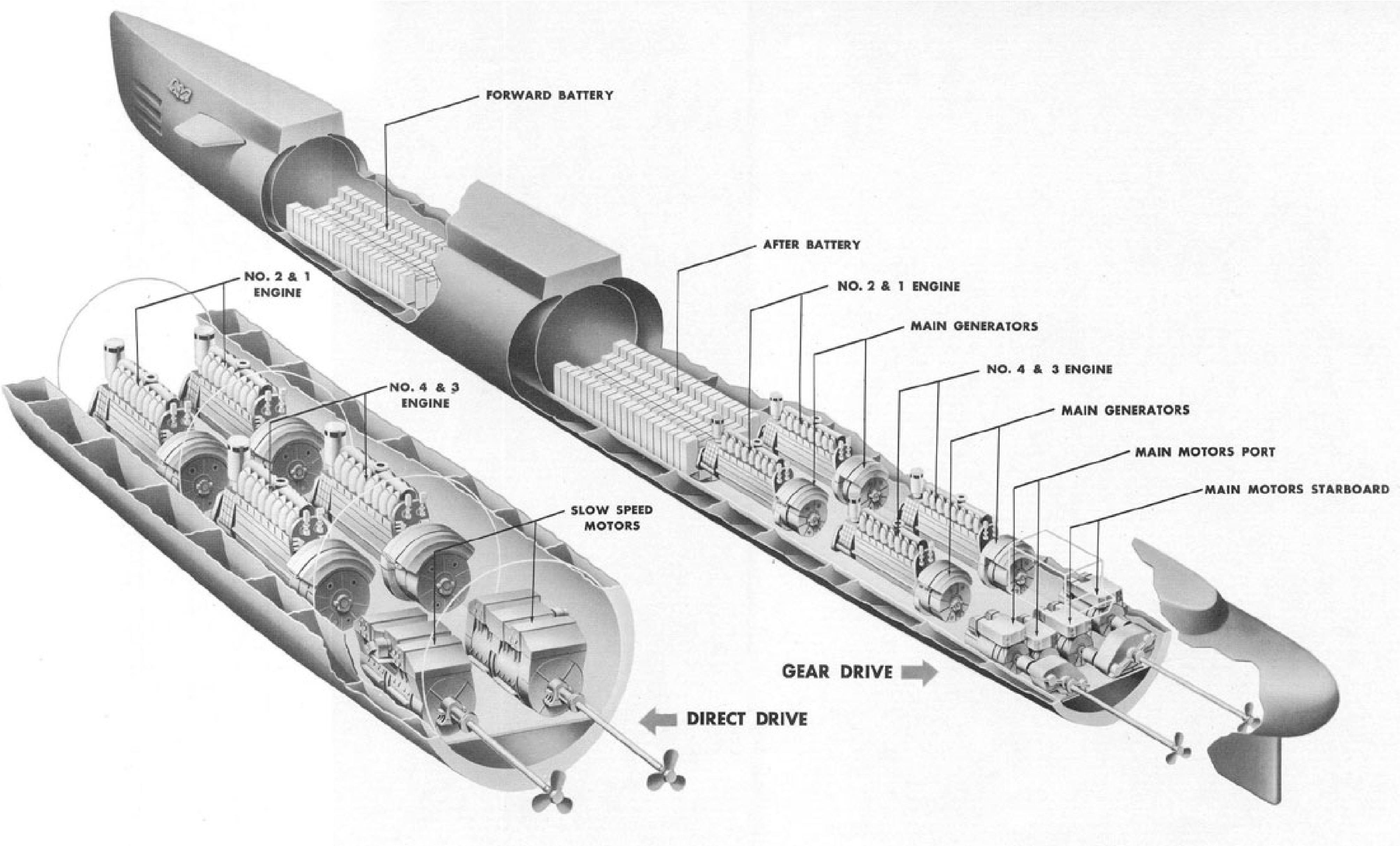
6. Auxiliary generator cable run from aft engine room to maneuvering room. The positive and negative leads of this circuit employ 4 type SHFL-650 cables (2 cables per leg), each of which is approximately 55 ft long.

7. Bus tie to auxiliary power distribution switchboard. This circuit runs from the maneuvering room to the control room and employs 4 type SHFL-650 cables (2 cables per leg), each of which is approximately 150 ft long.

8. Shore connection. This circuit runs from the after torpedo room to the maneuvering room and employs 4 type SHFL-650 cables (2 cables per leg), each of which is approximately 45 ft long.

Figure 2-1. GENERAL ARRANGEMENT OF MAIN PROPULSION EQUIPMENT, GEAR DRIVE AND DIRECT DRIVE.

Sub Elec. Home Page



Version 1.10, 22 Oct 04

3
MAIN CONTROL EQUIPMENT

A. DESCRIPTION

3A1. General. Fundamentally, the construction of the main propulsion control equipment or control cubicle produced by General Electric, Westinghouse, and Cutler-Hammer is similar. Individual components may vary somewhat in design; their locations and methods of installation in the assembly may differ; cables and conduits will be found routed differently; but each assembly as a whole performs the same function and is operated in a similar manner.

This chapter, with the exception of Sections 3A2 and 3B11, deals with the operation of the single unit type control cubicle. The discussion of the maintenance procedures and the procedure for detecting grounds (Section 3C4) applies to both single unit and split types of equipment. Details not covered may be found in the manufacturer's instruction book covering the specific equipment.

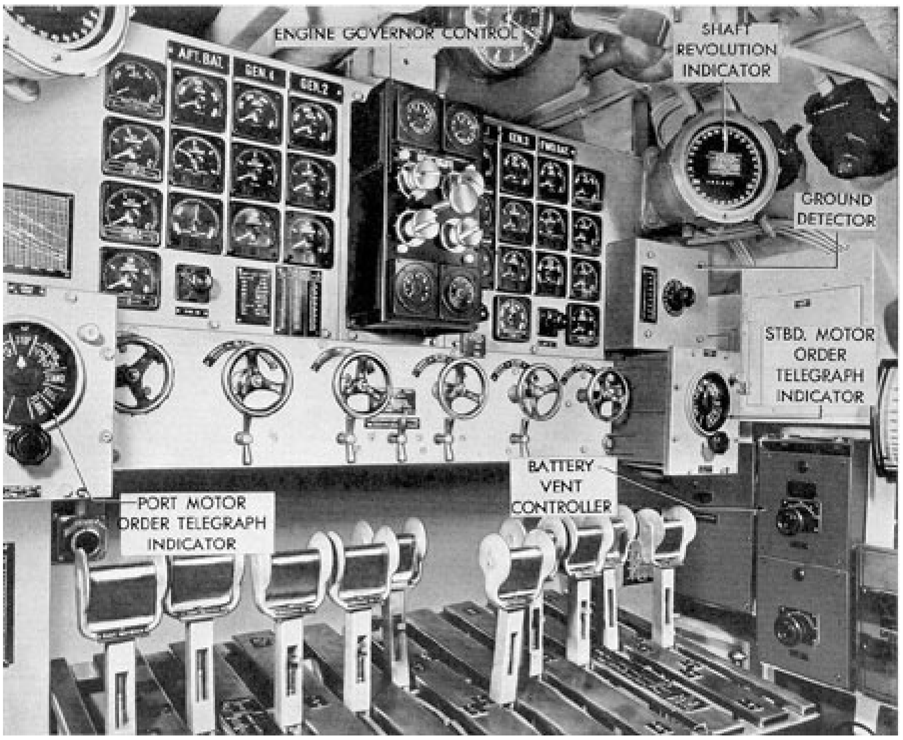


Figure 3-1. Front view of main control, installed.

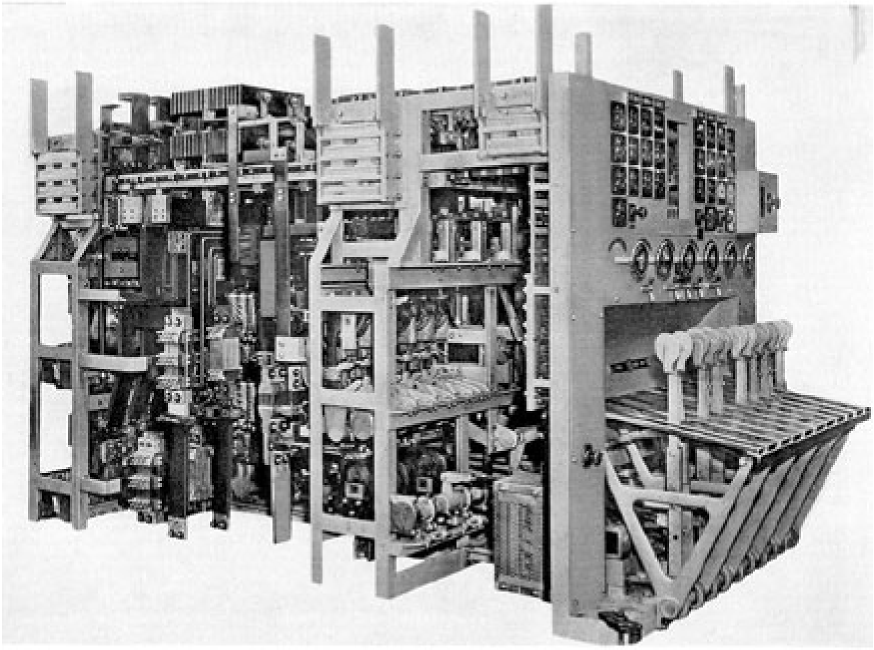


Figure 3-2. G.E. main control cubicle.

3A2. Split type main propulsion control equipment. The split type control equipment (Figure 3-5) is installed on some of the later type submarines on which double armature, slow speed, direct connected propulsion motors are used. This equipment performs the same functions as the single unit control cubicle, and with the minor exceptions noted in Section 3B11 is operated in the same manner.

The two halves of the control panel are essentially the same. Each half is mounted in a steel frame which is joined to the other to form a single structure and is shock mounted to the hull. The starboard control panel consists of the generator levers for the No. 1 and No. 3 generators, starting and reversing levers for the starboard motor, and a bus selector and forward battery lever. The port control panel consists of the generator levers for the No. 2 and No. 4 generators, starting and reversing levers for the port motor, and a bus selector and after battery lever.

3A3. Functions. The control equipment perform the following functions:

1. Starts, stops, reverses, and regulates the speed of the main motors for both surface and submerged operation.

2. Provides for series, parallel, or series-parallel connections of the motor armatures.

3. Provides for uniform speed control of the main motors throughout the entire range of propeller speed from about 38 rpm to 192 rpm submerged, and to about 280 rpm on the surface.

4. Provides for operating the main motors from one or both main storage batteries and from any combination of the main generators.

5. Provides for charging one or both storage batteries with main generators, individually or in combination. Main generators not being used for battery charging may be used for propulsion power.

6. Provides for driving the starboard motors from the starboard generators and the port motors from the port generators entirely independently of each other except for a common excitation bus.

7. Provides for operation ahead on one propeller shaft and astern on the other at any speed within the designated operating range.

8. Provides, by means of shore connections, for charging the main battery from shore or tender.

3A4. Simplified power circuit description. a. The main control cubicle circuit (Figure 3-6) consists essentially of two buses, the motor bus and the battery bus to which the main power units are connected by means of their associated contactors in order to provide the various operating combinations. The motor bus is the one to which the main motors are connected for any of the running conditions by means of their starting contactors.

The motor bus can be split for operation of the motors on one side independently of the other side (BUS TIE OPEN), closed for parallel operation of both motor groups (BUS TIE CLOSED), connected to the battery bus for battery operation of the main motors (BATTERY BUS), and lastly, for series operation of all motors, the positive side of one motor bus can be cross-connected to the negative side of the other motor bus, so that by proper closing of the motor contactors, all four motors can be placed in series for slow speed operation on the battery bus (SLOW).

Either or both batteries can be connected to the battery bus by closing their respective contactors which in turn are controlled by one operating lever.

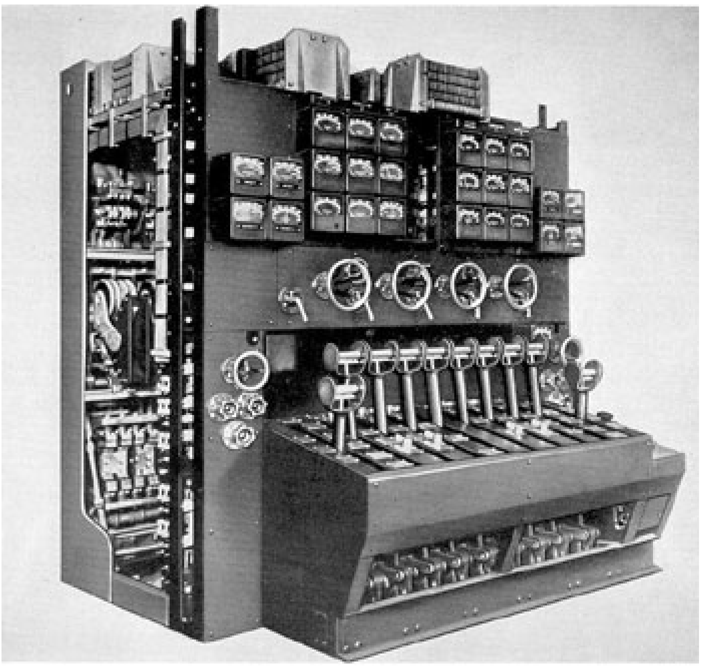


Figure 3-3. Cutler-Hammer main control cubicle.

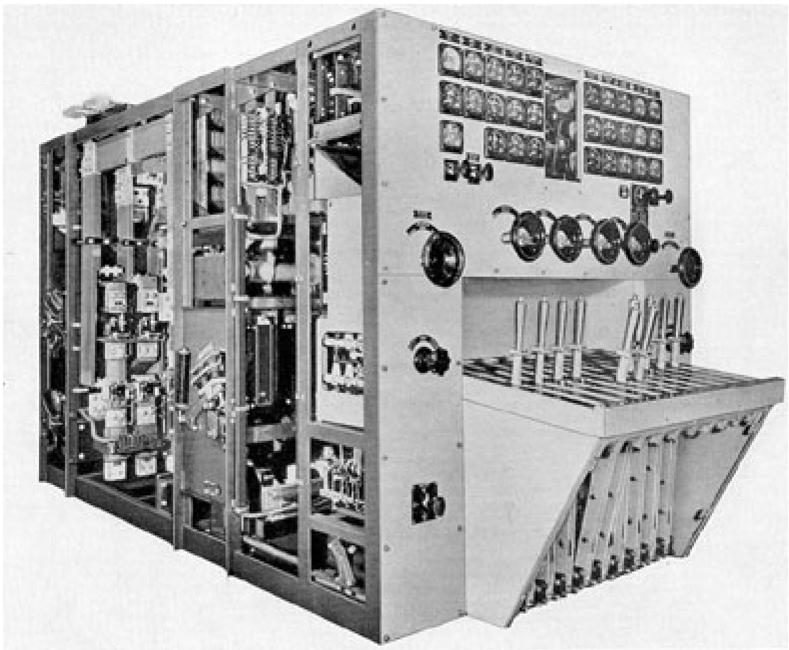


Figure 3-4. Westinghouse main control cubicle.

Each main generator has two sets of contactors so arranged that only one set can be closed at a time. One set when closed connects its generator to the battery bus so that the main battery can be charged from the generator. The other set connects the generator to the motor bus for driving the main motors. Associated with the main motors are contactors for 1) connecting the motors to the through a two-pole, double throw switch provided with a locking device for securing it in the OPEN position or in either of its CLOSED positions. This switch is connected to the battery cables on the battery side of the battery contactors in the control cubicle. The schematic diagram shows the motor fields connected in series. On some vessels, however, they are connected in parallel.

motor bus with the motors in each group in either series or parallel, and with the motors in series with their starting resistors; and 2) for shorting out the resistors as the motors come up to speed and the starting current reduces. Also associated with the motors is a switch group that provides for connecting the armatures of the motors in a reverse direction to operate the motors in the astern direction.

b. Excitation and control circuits. As indicated in Figure 3-7, excitation power is furnished from either the forward or after battery

e. Protective circuits. Motor, generator, and battery contactors are provided with overload protection of the trip-free, holding coil type. An overload relay is placed on each side of each armature and each battery. All overload relays associated with each group of contactors are connected in series with a holding coil. The holding coil is an electromagnet which, when de-energized, allows the trip-free mechanism to operate. For the description of this mechanism see Section 3A14. The protective circuits are shown in Figure 3-8.

3A5. Principal parts. The principal parts of the equipment are as follows:

1. One main propulsion control panel and operating bench with necessary instruments, rheostats, operating levers, etc.

2. One after contactor group comprising:

a. Port and starboard motor reversing switches.

b. Port and starboard motor starting contactors.

c. Bus selector switches.

3. One forward contactor group comprising:

a. Port and starboard main generator contactors.

b. Forward and after battery contactors.

3A6. Operating levers. There are 10 levers for the manual operation of the contactors in the various switch groups. These levers are provided with lock latches and are mechanically connected to the contactor camshafts by a series of bell cranks and rods. The purpose of the levers is as follows:

a. Two reverser levers. These levers are used to change the direction of rotation of the main motors by reversing the current flow through the armature. One lever is for the 2 starboard motors, and the other is for the 2 port motors. Each lever has 3 positions, AHEAD, OFF, and ASTERN.

b. Two starter levers. Each of the starter levers, 1 for the 2 port and 1 for the 2 starboard motors, has a STOP position and 5 operating positions, SER. 1, SER. 2, SER. 3, PAR. 1, and PAR. 2. The starter

c. Motor bus tie contactors.

All parts are mounted in a number of steel frames which are joined to form a unit. The assembly is supported on rubber shock mounts which are secured to the hull.

lever is used for cutting in a resistance in series with the armature, thus keeping the starting current down to a minimum. As the motor picks up speed, the resistance can be cut out of the circuit when the armature is at running speed and the current reaches a normal value, putting it across the line voltage. The starter levers have 3 series

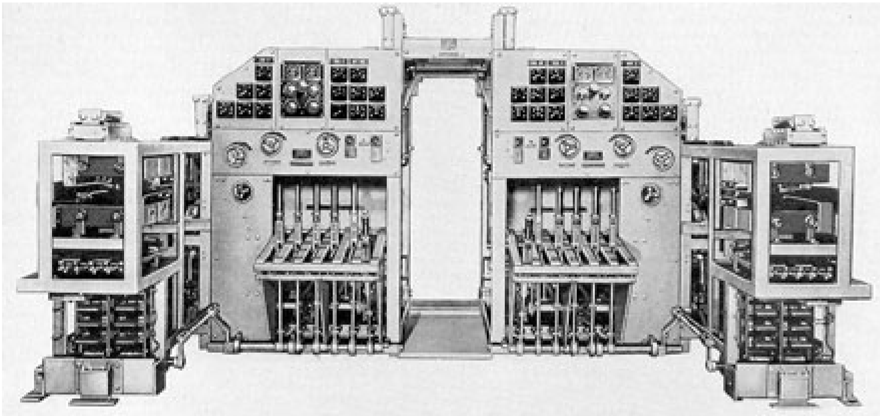


Figure 3-5. Split type main propulsion control cubicle.

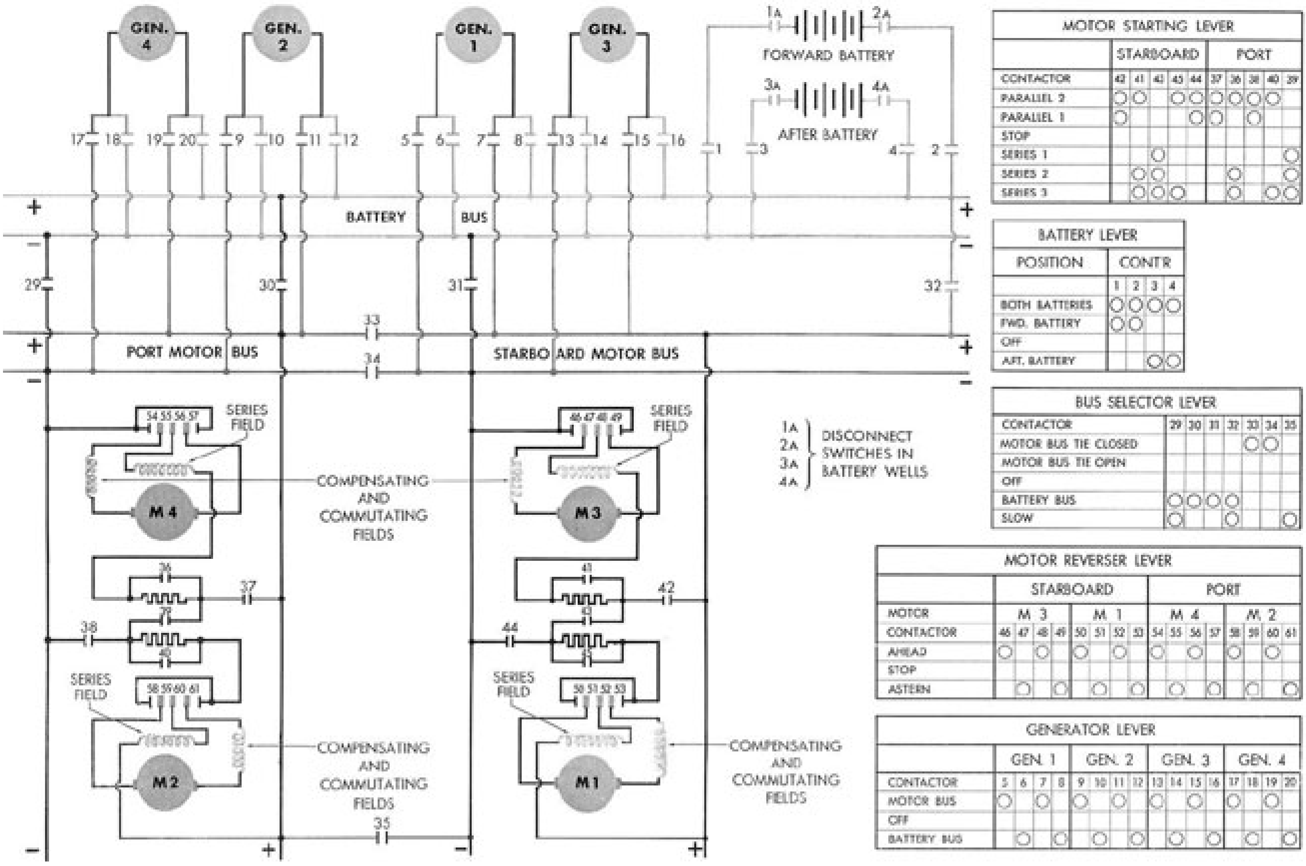


Figure 3-6. Schematic wiring diagram of main propulsion control.

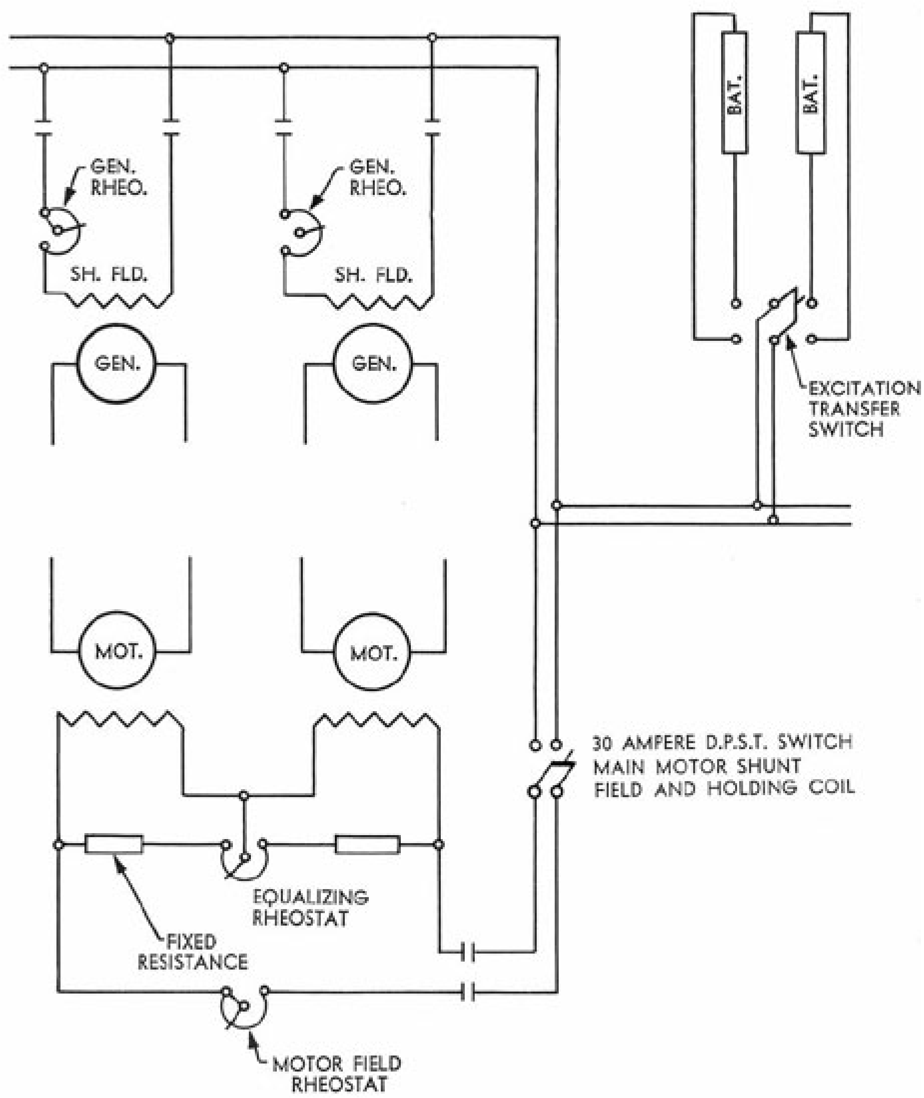


Figure 3-7. Excitation circuits.

positions and 2 parallel positions. The 2 motors on each shaft are always in series with each other when the starters are in any of the 3 series positions, the voltage of the line being divided between each of the motors. When the starters are in either parallel position, the 2 motors on each shaft are in parallel, each motor receiving the full line voltage, The SER. 3 and PAR. 2 positions are the only running positions of the starter levers. Since the starting resistances are

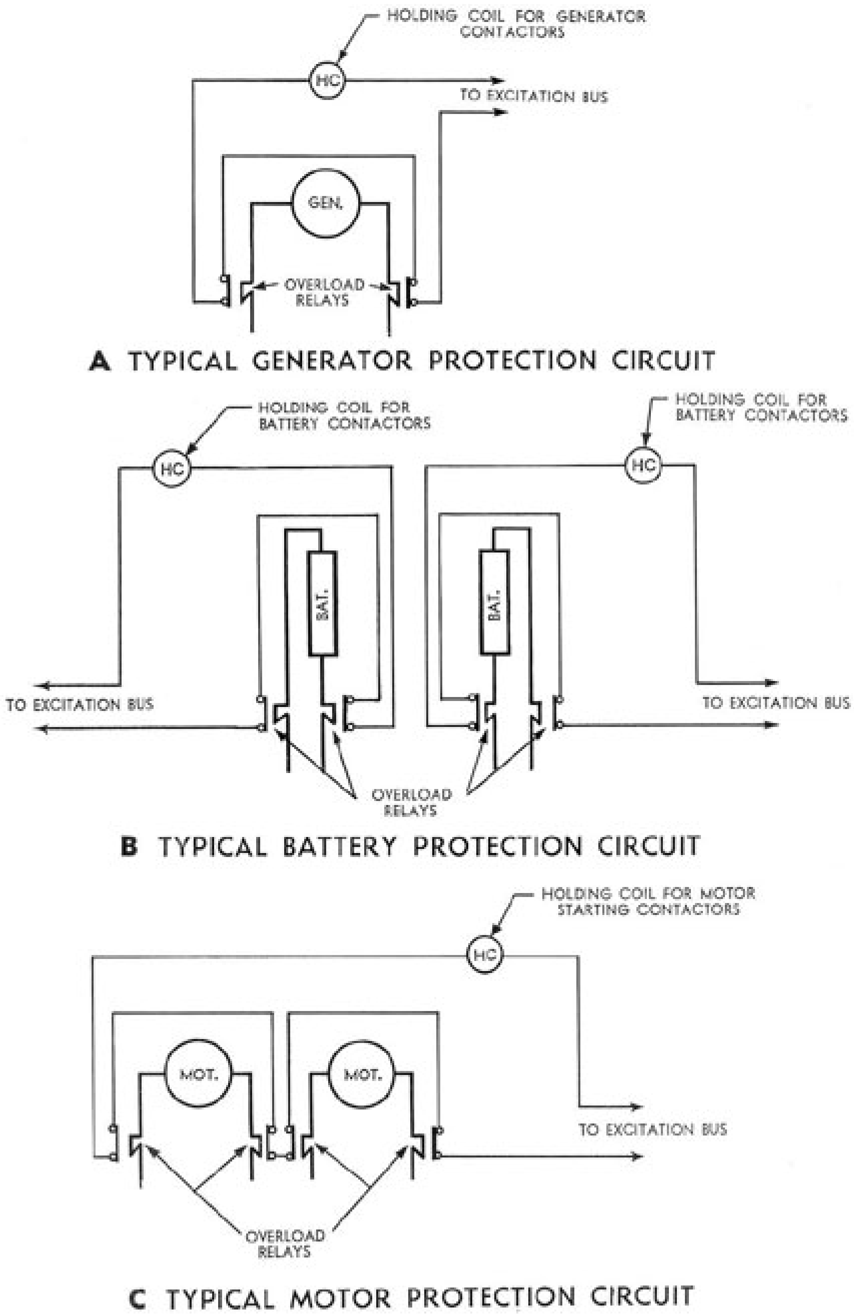


Figure 3-8. Protective circuits.

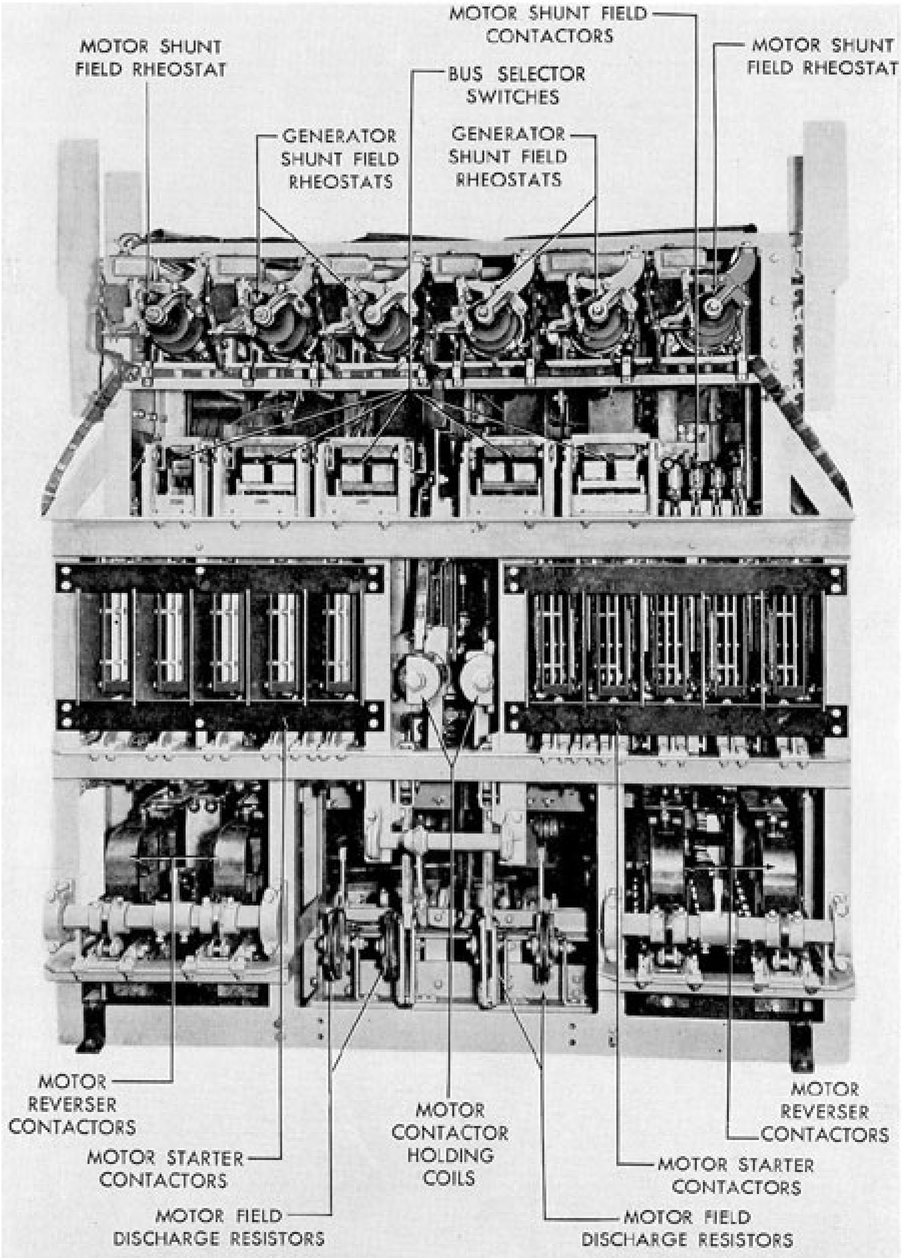


Figure 3-9. After-side view of G.E. after contactor group.

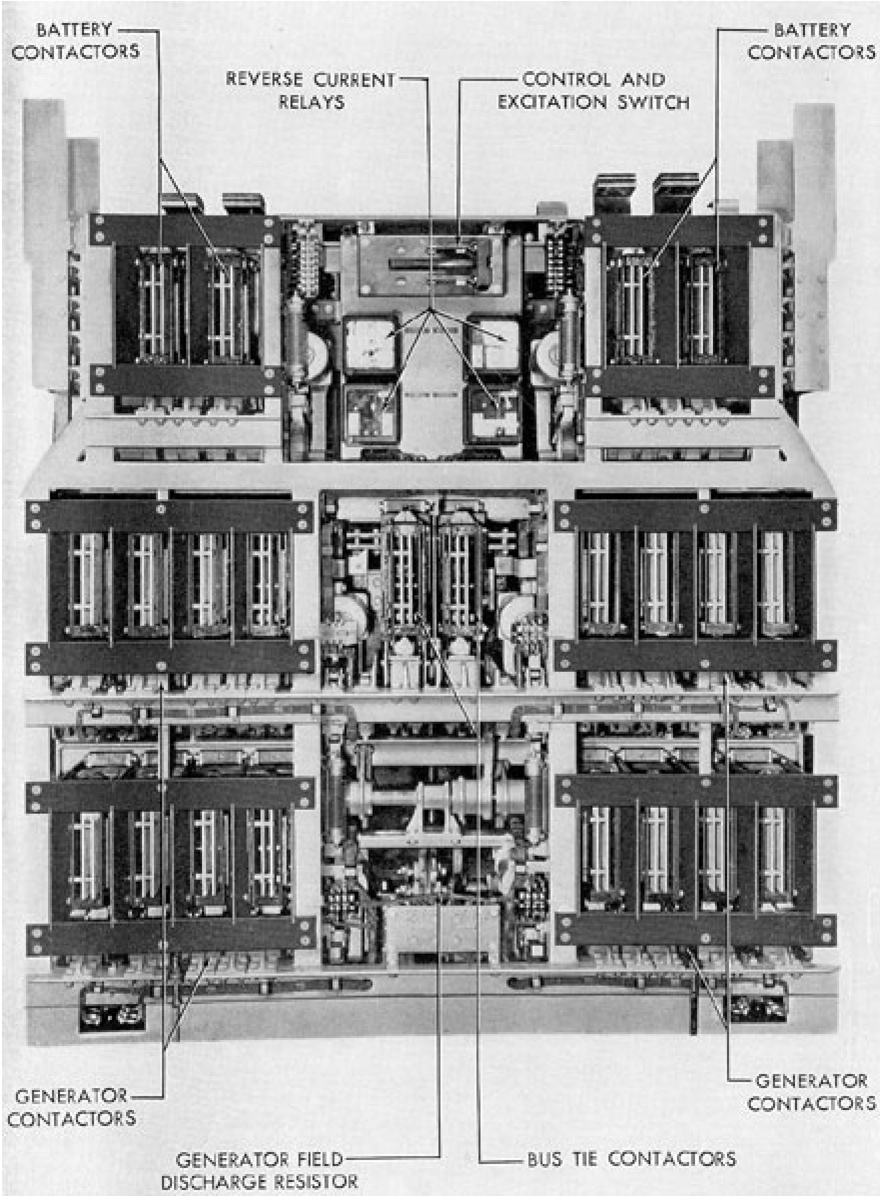


Figure 3-10. Rear view of G.E. control equipment.

designed to carry current for short periods only, the starting levers should never be left in SER. 1, SER. 2, or PAR. 1 longer than is, necessary for the current to decrease to normal.

c. Four generator levers. One lever is provided for each of the 4 main generators. The levers have an OFF position and 2 operating positions, MOTOR BUS and BAT. BUS.

NOTE. On Westinghouse controls the operating positions are GEN. BUS and BAT. BUS.

AFT. BAT., FWD. BAT., and BOTH BAT. Placing the lever in the AFT. BAT. position will place the after battery on the battery bus. Placing it on the FWD. BAT. position will place the forward battery on the battery bus. In the BOTH BAT. position, both batteries are in parallel with each other and on the battery bus. The battery bus is a common connection which is supplied with current from either one or both batteries and which in turn supplies current to the motor bus for motor propulsion when the bus selector is in the battery position. In addition, any desired

The function of these levers is to place any desired generators on the battery bus for charging the batteries, or any one or all of the generators on the motor buses for propulsion. An extra mechanical latch on each lever prevents accidental movement from the OFF position.

d. One battery selector lever. This lever has an OFF position and 3 operating positions, generators may be placed on the battery bus to charge either one or both batteries as desired. When the battery bus is used only for charging, it is necessary to have only the battery selector and the charging generator on the battery bus; the bus selector can be in the OFF position.

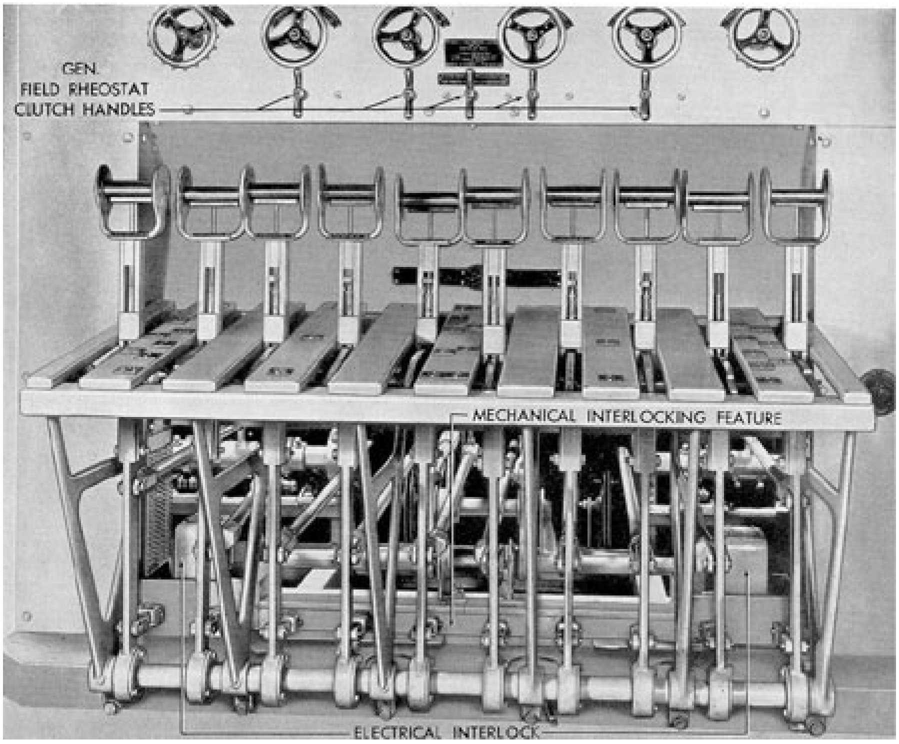


Figure 3-11. Operating levers.

e. One bus selector lever. The bus selector has 5 positions: BUS TIE CLOSED, BUS TIE OPEN, OFF, BAT. BUS, and SLOW. The functions of this lever are to connect the port and starboard motor buses, to connect the battery bus with the motor bus, and to close the necessary contactors to operate all four motors in series.

3A7. Mechanical and electrical interlocks. The 10 operating

NOTE. On Cutler-Hammer and Westinghouse equipment this interlocking function is not present.

6. The auxiliary latch must be lifted before a generator lever can be thrown to the MOTOR BUS or BAT. BUS position. To operate a lever with an auxiliary latch requires the use of both hands, the object being to make the operator realize the importance of the step and

levers have notched steel bars attached to them and mechanically interlocked with each other by slide bars. In addition, an electrical interlock is provided on each starter lever. This interlock consists of a solenoid whose circuit is completed by cam-operated contacts attached to the shaft of the field rheostat handwheel. The resulting interlocking arrangement of the operating levers is as follows:

1. A motor starter lever cannot be moved from the STOP position unless the corresponding motor field rheostat is in at least 75 percent full field position (electrical interlock).

2. The reverser lever cannot be moved unless the corresponding motor starter lever is in the STOP position.

3. The battery lever cannot be moved if the bus selector lever is in the SLOW or BAT. BUS position except that it may be moved between the FWD. BAT. and BOTH BAT. positions at any time.

4. The bus selector lever cannot be moved unless both motor starter levers are in the STOP position, except that the bus selector lever can be moved between the MOTOR BUS-BUS TIE OPEN and MOTOR BUS-BUS TIE CLOSED positions at any time. The motor starting levers cannot be moved when the bus selector lever is in the OFF position.

5. A generator lever cannot be moved from the OFF position to cause him to think before he makes a particular selection.

7. The bus selector lever cannot be thrown to the BAT. BUS or SLOW position unless all generator levers are in the OFF or BAT. BUS position, nor can any generator lever be thrown to the MOTOR BUS position if the bus selector is in the BAT. BUS or SLOW position.

3A8. Overload relays. Each battery, motor, and generator is protected against short circuit and overload by means of overload relays connected as shown in Figure 3-8. The overload relay contacts open when the current exceeds a certain value, thus de-energizing the holding coil and permitting the contactors in the overloaded circuit to open.

The relays are provided with adjustable, calibrated tension springs for the purpose of adjusting the current at which the relays open. Since the relays are of the instantaneous acting type, they must be set rather high to prevent tripping due to current peaks which may occur during starting and maneuvering. The battery relay is usually set for 12,000 to 14,000 amperes. The generator and motor relays are usually set for 10,000 to 13,000 amperes. For specific calibrations of the various relays refer to the manufacturer's instruction book.

3A9. Reverse current protection. A reverse current relay (Figures 3-13 and 3-14) is provided for each main generator to protect it and its driving engine when charging batteries. These relays are adjusted to operate at a low reverse current value. In the event of reverse

the MOTOR BUS position unless the bus selector is in the OFF position.

CAUTION. If one generator is already in the MOTOR BUS position, any other can be thrown at will. Hence this interlocking arrangement does not prevent the operator from placing a dead generator on a live motor or battery bus and seriously damaging the machine.

current flow (current flowing from battery to generator) of sufficient value, the relay contacts open, thus deenergizing the holding coil circuit and causing the generator contactors to open. The relays normally are set to operate at 300

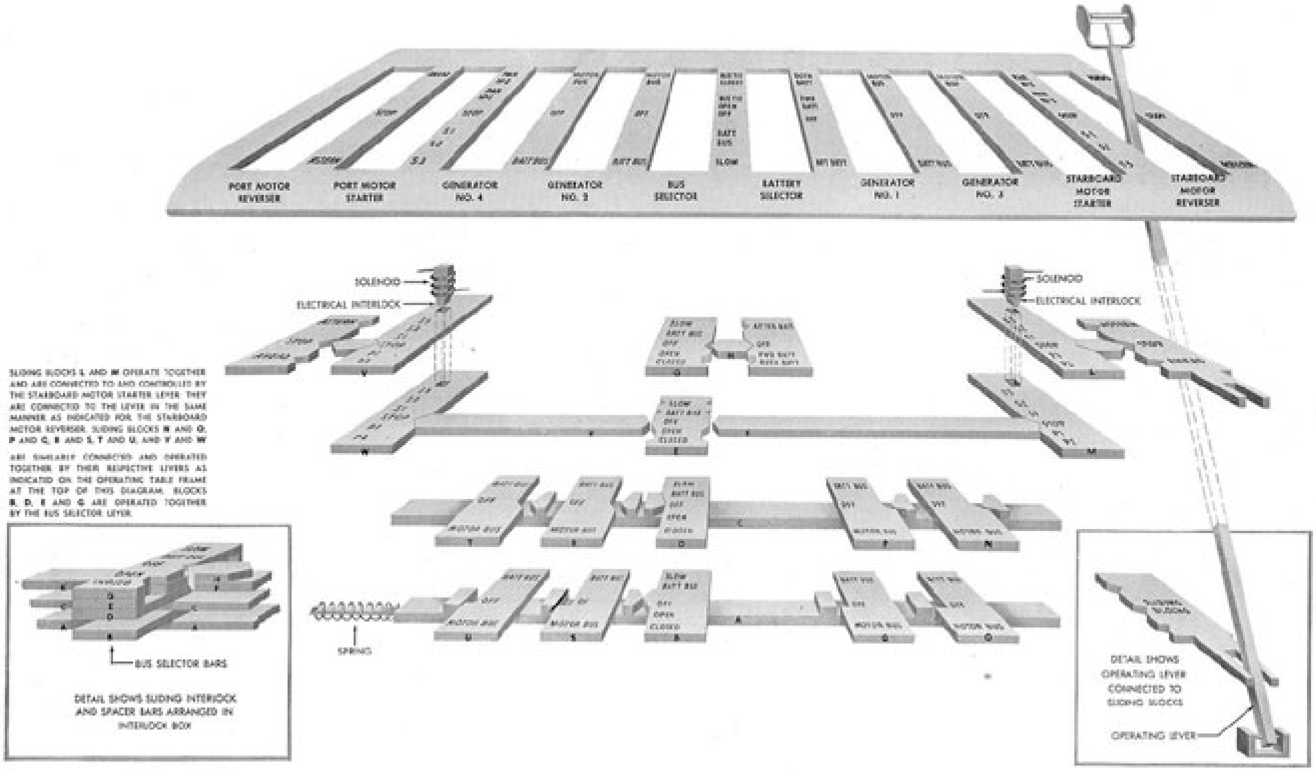


Figure 3-12. Diagram of Interlocking arrangement.

amperes and 250 volts. These relays are nonoperative if the generator is supplying power to the motor bus.

CAUTION. These relays do not act in sufficient time to prevent damage to a generator if it is accidentally connected to the battery when it is not rotating, or if its field is not energized.

3A10. Field discharge resistors. The field discharge resistors connected across each generator and motor shunt field serve to limit the inductive voltage rise across the field during opening of the field switch. The resistors used

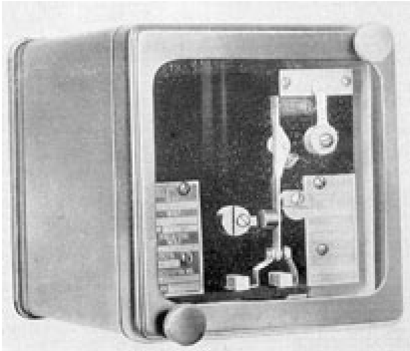


Figure 3-13. Main generator reverse current relay, closed.

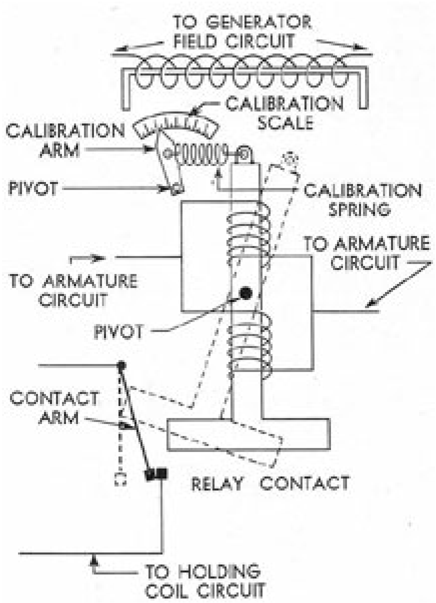


Figure 3-14. Schematic diagram of main generator reverse current relay.

on Cutler-Hammer and Westinghouse equipment consist of wire wound resistors connected across the field terminals just before the field circuit is opened. General Electric employs "Thyrite" (trade name) units (Figure 3-15) which are composed of a ceramic material, having very high resistance at low voltages and low resistance at high voltages. They are permanently connected across the field terminals. In both types of installation, the energy of the discharging field is dissipated in the resistors in the form of heat, thereby protecting the field coils from the high voltage that results from the sudden opening of an inductive circuit.

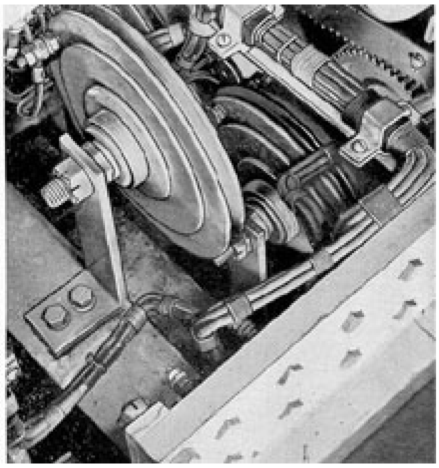


Figure 3-15. GE "Thyrite"field discharge resistor.

3A11. Motor and generator field rheostats. The 2 motor rheostats port and starboard, and the 4 main generator rheostats are of similar design. General Electric employs a fixed commutator type, the individual bars of the commutator being connected to taps on the field resistor. The contact brush is rotated through bevel gearing by a handwheel on the front of the panel. Each rheostat has 90 steps of resistance.

Included on each of the 4 generator rheostat-operating shafts are 2 cam-operated generator field contactors, the cams being so arranged that the contactors open after all resistance has been inserted in the field circuit. The motor field rheostats also have 2 cam-operated contactors. One, which closes in the full field position, serves to bypass the rheostat. The other, which closes at 75 percent full field position, completes a circuit to an electrical interlock on the motor starting lever. Westinghouse and Cutler-Hammer rheostats are of the face plate type design, employing a contact arm which travels over a number of contact points mounted on a face plate, with the resistance bank mounted behind the face plate. The Westinghouse and Cutler-Hammer generator rheostats are not equipped with field contactors.

Whenever 2 or more main generators are operated in parallel, their field rheostats can be clutched together and driven from any one of the handwheels. However, the Cutler-Hammer clutching mechanism is so arranged that the rheostats cannot be tied together until they are in identical positions, whereas the arrangement on General Electric and Westinghouse permits clutching of the rheostats regardless of their relative positions.

Figure 3-16. Field rheostat, G.E. commutator type.

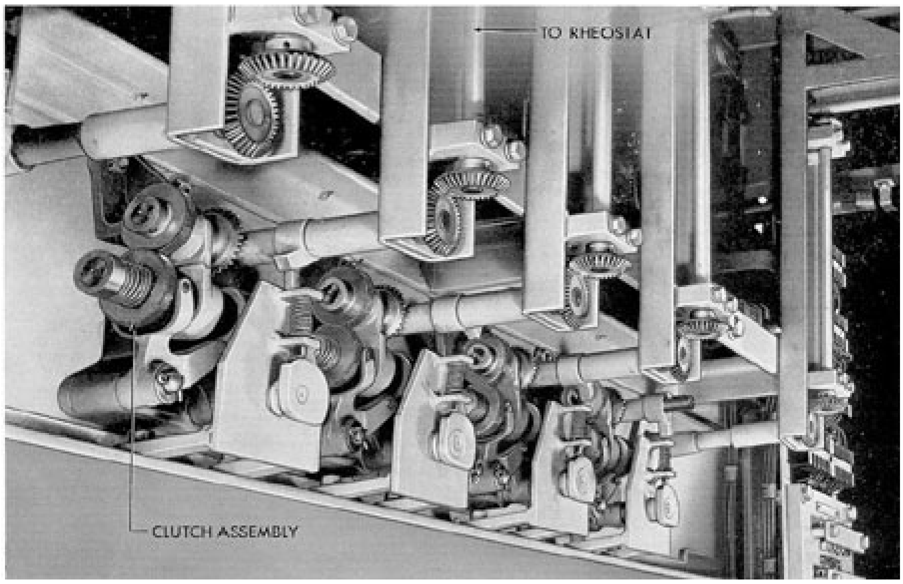


Figure 3-17. G.E. field rheostat clutch mechanism.

3A12. Vernier rheostats. Two load-balancing rheostats, sometimes called vernier rheostats, are provided, one for the two port and one for the two starboard motors. By acting to strengthen the field of one motor and at the same time weaken the field of the other motor, they provide a manual means of equalizing the load between the two motors on one shaft when they are operating in parallel.

3A13. Motor starting resistors. One starting resistor is provided for each motor armature. These resistor units consist of steel straps or cast grids made of an alloy containing mainly nickel, copper, and iron. The capacity of the resistors is sufficient to carry the full motor armature starting current for approximately 1 minute when the motor starting lever is in SER. 1 position, plus 1 minute in the SER. 2 position, and 1 minute in the PAR. 1 position, provided the motors are operated for 1 minute in the SER. 3 connection when moving from SER. 2 to PAR. 1.

The resistors will stand a duty cycle of 2 minutes on, 1 minute off, and 1 minute on with 900 amperes flowing through the resistors, and not exceed 390 degree C during this cycle. These resistors are located overhead between the forward and after contactor groups.

3A14. Contactors. All contactors that may be required to operate under load are provided with arc chutes and magnetic blowout coils for circuit interrupting duty. All contactors, with the exception of the motor bus-bus tie contacts and the contactors which short out the starting resistance have, incorporated in their operating mechanism, a trip-free feature that allows the contactor to open independently of camshaft position. After such opening, due to overload, reverse current, and so forth, the camshaft must be returned to the OFF position to reset the trip mechanism before the contactor can again be closed.

3A15. Ground detector equipment. The ground detector equipment provided on the main control panel consists essentially of the following parts:

1. A double-scale voltmeter with a range from 0 volts to 500 volts on both sides of the center.

2. A rotary selector switch for selecting the particular circuit to be tested on motors or generators.

3. A battery selector switch for selecting the particular battery or polarity to be tested, either positive or negative alone, or both.

4. A resistor and push-button switch connected in parallel with the voltmeter. The purpose of this circuit is to lower the effective resistance of the voltmeter circuit to one-tenth of its regular value. It

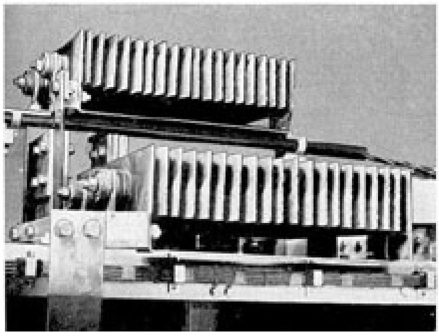


Figure 3-18. G.E. main motor starting resistors.

is provided primarily to increase the accuracy of measurement of low insulation resistance that is encountered on main power cables when they are carrying full load current continuously.

Instructions for the operation of this equipment are given in Section 3C4.

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Figure 3-19. G.E. main motor starting contactors, arc chutes removed.

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B. OPERATION

3B1. General. While all contactors are designed to break any normal operating current, contactor maintenance can be kept at a minimum by reducing, whenever possible, the current broken by the contactor to its lowest amount before opening the contactor.

When moving the operating levers from one position to another, the operation should be

If greater speed than that obtained in the SLOW position is desired, the selector lever should be placed in the BAT. BUS position and the starter lever in the SER. 3 position.

CAUTION. The holding coil control switch should be opened slowly to allow for collapse of the induced voltage in the coils. Sudden opening of the switch may cause an induced voltage that will break

firm, fast, and positive. Slow or hesitant operation will draw out sustained arcs between the arc tips, thereby causing excessive burning. However, this does not mean that they should be slammed from one position to another as this will cause rapid wear of the parts. One exception to this rule should be noted: When moving the motor-starting lever from a SERIES position to a PARALLEL position, a momentary positive stop is made in the STOP position before moving into the PARALLEL position. This allows time for the series contactor arc to collapse before the parallel contactors are closed. This stop is also necessary when returning from the PARALLEL position to the SERIES position.

CAUTION. If this precaution is not observed the supply may be effectively short circuited and the resulting fire will certainly damage the control equipment. This casualty has occurred several times in submarines on patrol, putting the control cubicle out of commission.

In operating the starting lever in a sequence of positions, the motor ammeters indicate a sudden high current as each position is reached, but, as the speed of the motor increases, this current decreases to a more or less steady armature current, indicated by a steady position of the motor ammeter pointer. The most successful operation of the motor control is obtained by waiting for a steady motor ammeter indication while in one lever position before moving the lever to the following position. down the circuit insulation so that repair or replacement will be necessary.

When using the same number of generators on each side, the bus selector lever should be in the MOTOR BUS TIE OPEN position, thereby disconnecting the port and starboard motor buses. For one-generator or three-generator operation, it should be in the MOTOR BUS TIE CLOSED position in order to supply equally both port and starboard motors, and for balancing the generator loads. For two-generator or four-generator operation, when the generators are divided equally between port and starboard, the bus selector lever may be in either the CLOSED or OPEN position. The OPEN position is preferred because it tends to prevent an electrical fire from spreading from one side of the cubicle to the other and permits independent control of the motors and generators on each side. Further, opening of contactors under overload on one side will not affect the operation of the other side.

In parallel operation of main generators, with the generator field rheostats mechanically clutched together for common operation, a mechanical interlock on each clutch handle prevents the turning of any rheostat far enough to disconnect its field. On older type GE controls this is accomplished by a switch on the clutch that bypasses the field contactors. The clutch cannot be engaged for combined operation if the field contactors are open.

It is possible for the bus selector lever to be moved from the BUS

The normal operating position of the starter levers for SLOW operation (that is, with the bus selector in the SLOW position) is in the SER. 3 position. If the starter levers are moved to the PAR. 1 and PAR. 2 positions, thereby increasing the propeller speed and motor load, the series selector contactor will be overloaded.

TIE OPEN to the BUS TIE CLOSED position at any time, thereby possibly throwing generator bus voltage across nonrotating motors or generators. Before moving the BUS selector lever from the BUS TIE OPEN to BUS TIE CLOSED position, make the following checks:

1. Check to see that the voltmeters for all generators that are connected to the motor bus read the same voltage. If not, either adjust the generator rheostats until they do or disconnect from the motor bus.

2. Check to see that if the generator levers in one side (port or starboard) are not in the MOTOR BUS position that the starter lever on that side (port or starboard) is in the STOP position.

For one- or two-generator operation always operate motors in series. For three- or four-generator operation always operate motors in parallel.

3B2. Optimum operating conditions. Detailed instructions for starting and operating the propulsion system in various combinations are given in the manufacturer's instruction book for the vessel. Due to the slight differences among the interlock systems for the several classes of submarines, it is not possible to give a single set of operating instructions that will cover all systems correctly. In order to get

current. At full load, the generator should always be run at, or slightly above, rated voltages, but not below.

3B4. Adjustment of motor field current. While submerged, the motor field strength is the only control over the speed of the vessel (aside from the connection of the armatures in various combinations of series and parallel). On the other hand, when operating from the generators, the fields of the motors are adjusted to obtain the desired output from the engines. When starting and maneuvering, the field should always be kept at full strength to increase the available torque and reduce current peaks. For steady operations, the motor field current should be adjusted to give the desired load on the generators being used. It varies, depending on the number of engines used for propulsion. For example, with one engine on propulsion with the two motors on each side in series, it is necessary to weaken the motor field to about 80 percent of normal to load the generator to its full rated load. With two engines, one on each side, and the two motors on each side in series, the

the best in performance and reliability out of the propulsion system, there are a few fundamental points which must be observed. They apply equally to all types of electric drive submarines, although the exact values of current, voltage, speed, and so forth, must be obtained from the manufacturer's instruction book.

3B3. Adjustment of generator field current. In general, the best engine operation requires that the generator be run more slowly as the power output becomes less. The power is equal to the product of the voltage and the current produced by the generator. Since the voltage depends on the speed and field current, if the field current remains constant and the speed is reduced as the load is lessened, the generator voltage will decrease in proportion to the load. This condition requires that the armature current remain constant for all loads. Since the major part of the losses is due to the armature current and since the ventilation becomes less as the speed is reduced, the net result is overheating of the generator. Therefore, the best results are obtained when the generator is run at the maximum speed compatible with good engine performance and also at maximum field

motor fields must be weakened still more, (to approximately 62 1/2 percent of normal) to fully load the two engines. For three generators on propulsion, with all four motors connected in parallel, the motor fields must be increased to approximately 110 percent of normal to obtain a full load on the engines. For four generators, full load should be obtained with normal full field on the motors. However, under conditions of foul hull and so forth, full load may be reached at a propeller speed lower than designated, in which case more than the normal field will be required. This condition is unfavorable to the motors as it has the effect of reducing the series field, causing poor parallel operation. Therefore, should full load be reached at a propeller speed less than that designated, operation should be restricted and when used, the voltage of the system should be made as high as possible by increasing the generator field current.

3B5. Maneuvering. Maneuvering should always be performed on an even number of generators divided between the two sides. This makes it possible to control the two shafts entirely independently of each other and also to control the speed by generator field control which makes much smoother operation possible.

When planning to use three generators, it is easier to start on two and add the third later. Maneuvering on the battery may be used whenever the

and its rheostat and governor control clutched to the others. As the new generator heats up, it will drop part of its load and

maneuvers are not to last long or when maximum power is required immediately. When maneuvering on the battery, care should be taken to allow current peaks to die down to a steady state before proceeding to the next position on the starting lever.

3B6. Reversing. A quick reversal can be made either from the generators or the battery. For a generator reversal, it is desirable to have an even number of generators so that if an overload relay is tripped, power to only one screw would be affected. Reversal from the battery may be used when only one engine is in use at the time or for other reasons. On some vessels a reversal on the battery can be made faster than on the generators, but on others, which require the generators to be taken off the motor bus first, it takes approximately the same time. Maximum braking effect will be obtained when the current is held to a maximum (approximately 150 to 200 percent) and the transitions when no power is put out, are made as fast as possible. The recommended procedure for reversal on the engines is as follows:

1. Turn motor field rheostat to maximum.
2. Reduce engine speed to minimum.
3. Turn generator field rheostat to minimum but do not open.
4. Move starter lever to STOP.
5. Move reverser lever to BACK.
6. Move starter lever to SER. 1 and then to SER. 2 and SER. 3.

necessitate declutching and readjustment of the rheostat.

3B8. Propulsion from auxiliary generator. On a few vessels it is possible to put the 300-kw auxiliary generator on propulsion entirely free of the battery. However, on most vessels this is not possible. The auxiliary generator can, however, be used for propulsion without raising the battery voltage to the undesirable values which result in excessive evaporation. This is done as follows:

1. Start the auxiliary generator and connect to the battery. Adjust its voltage to 260 to 270 volts.

2. Start the motors from the battery and run in series. Adjust the motor field rheostat to give the desired shaft speed, being careful not to exceed the current rating of the auxiliary generator.

3. Make final adjustments of voltage with the auxiliary generator field rheostat, and of current with the motor field rheostat.

The above procedure is based on the assumption that the battery is fully charged. If the battery is being charged, the voltage must necessarily be determined by the state of the battery charge. It should be noted that the auxiliary generator must carry all auxiliary power as well as propulsion, and the current, therefore, should be read from the auxiliary generator ammeter rather than from the ammeters on the control cubicle.

3B9. Battery charging with a propulsion generator. Any propulsion generator not being

7. Increase engine speed.
8. Increase generator speed.

All steps should be made smoothly with the current maintained as close to maximum as possible. If too much power is used in reversing, the propeller will cavitate and no increase in braking effort will be obtained.

3B7. Adding a generator to a live bus. Whenever a generator is added to a live bus, its voltage should be adjusted to slightly above that of the bus. This will prevent reverse current from flowing to the generator. When adding a generator to the motor bus, its speed and load should be equalized with the others on the bus

used for propulsion may be placed on battery charge. It is necessary only to adjust its voltage slightly above battery voltage and throw its lever to BAT. BUS. The charging current is adjusted with the generator field rheostat. One battery may be charged independently of the other by placing the battery selector lever in the position for the battery to be charged.

CAUTION. Make certain that the auxiliary power bus tie does not parallel the two batteries when they are not paralleled in the propulsion control cubicle. The auxiliary power bus tie should never be closed except when all

auxiliary power is being obtained from one battery, the auxiliary generator, or the shore connection.

3B10. Operation. In Figures 3-20 to 3-27 are shown, for General Electric single unit propulsion control equipment, the movements and final position of the operating levers for various operating conditions noted in the titles. These

positions will be similar in the other manufacturers' equipment but the specific instruction book for the equipment in use must be consulted for the exact operating procedure before attempting operation, as the sequence of handling of the control levers varies with the different makes of equipment.

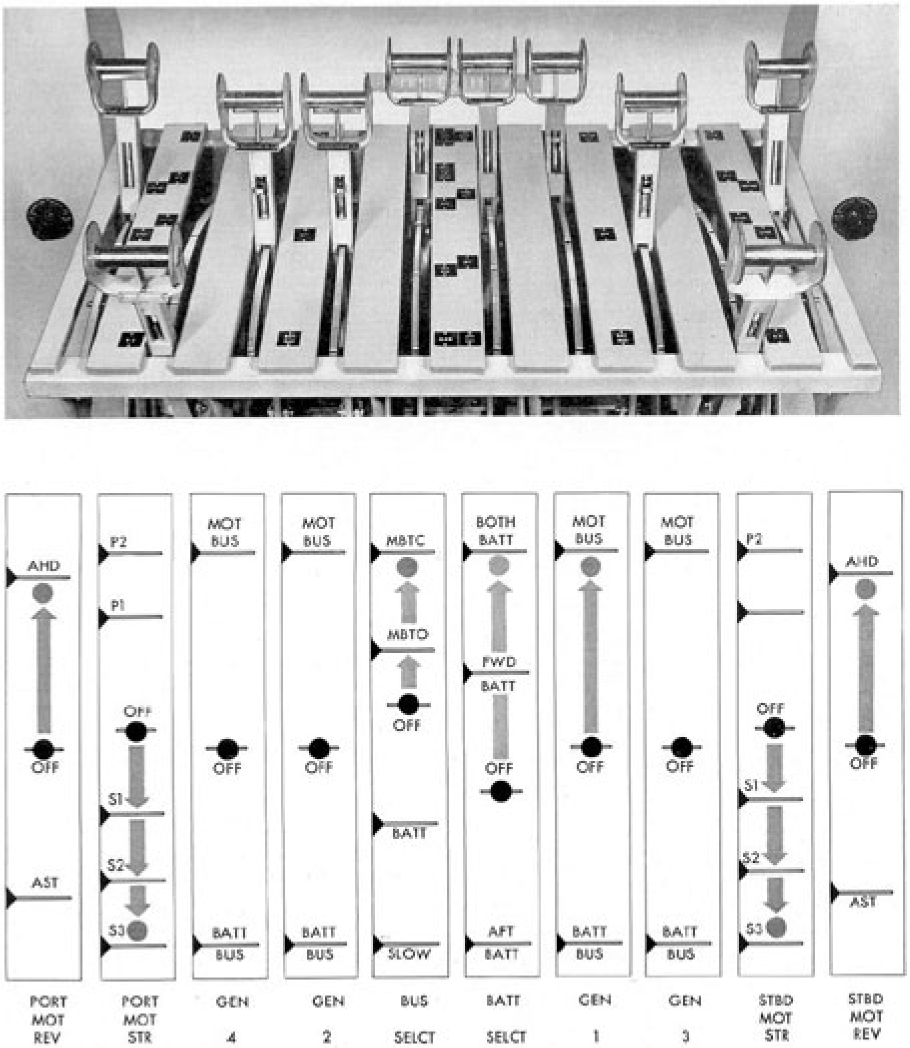

Figure 3-20. Position of operating levers for one-generator operation.

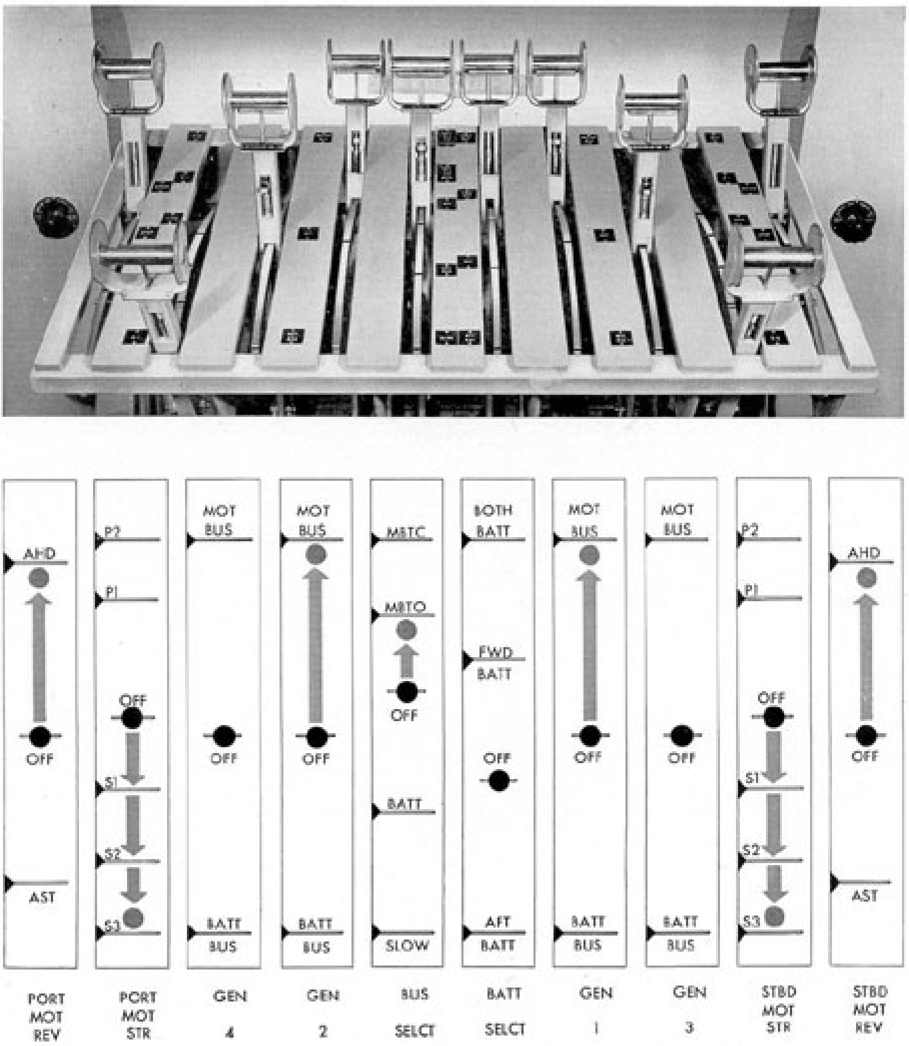

Figure 3-21. Position of operating levers for two-generator operation.

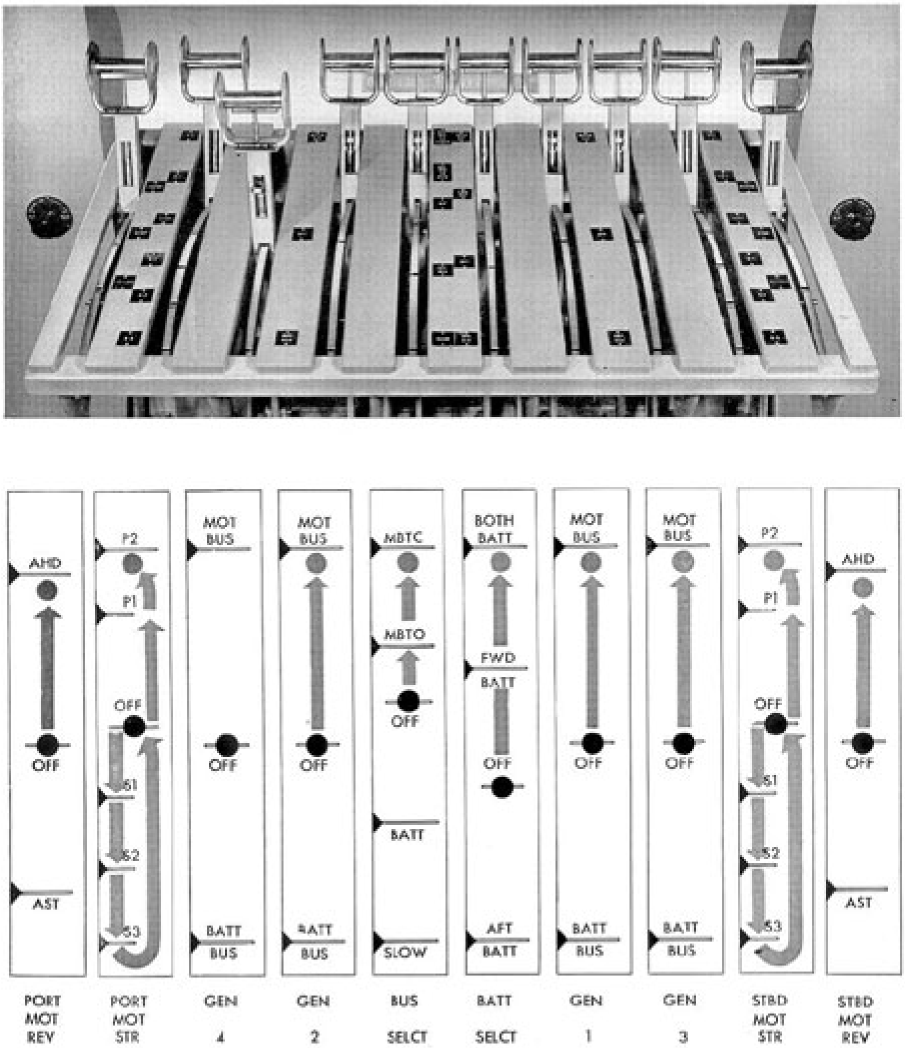

Figure 3-22. Position of operating levers for three-generator operation.

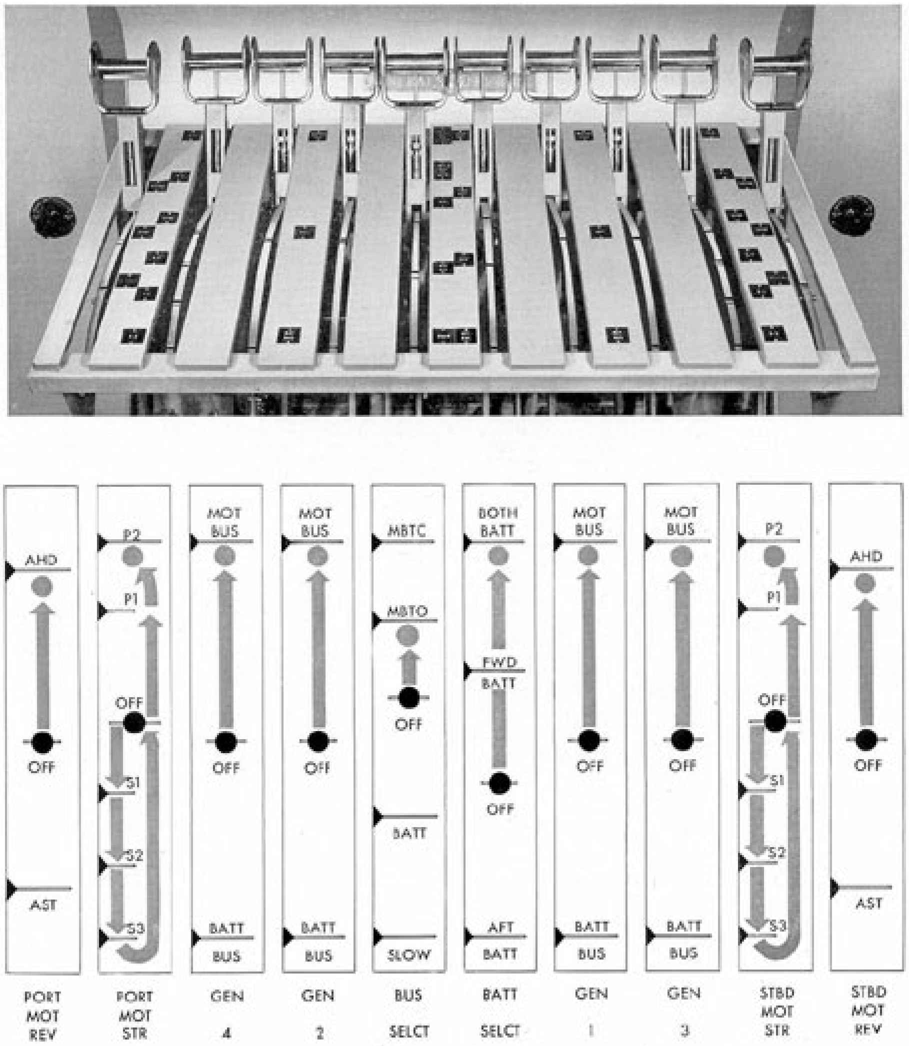

Figure 3-23. Position of operating levers for four-generator operation.

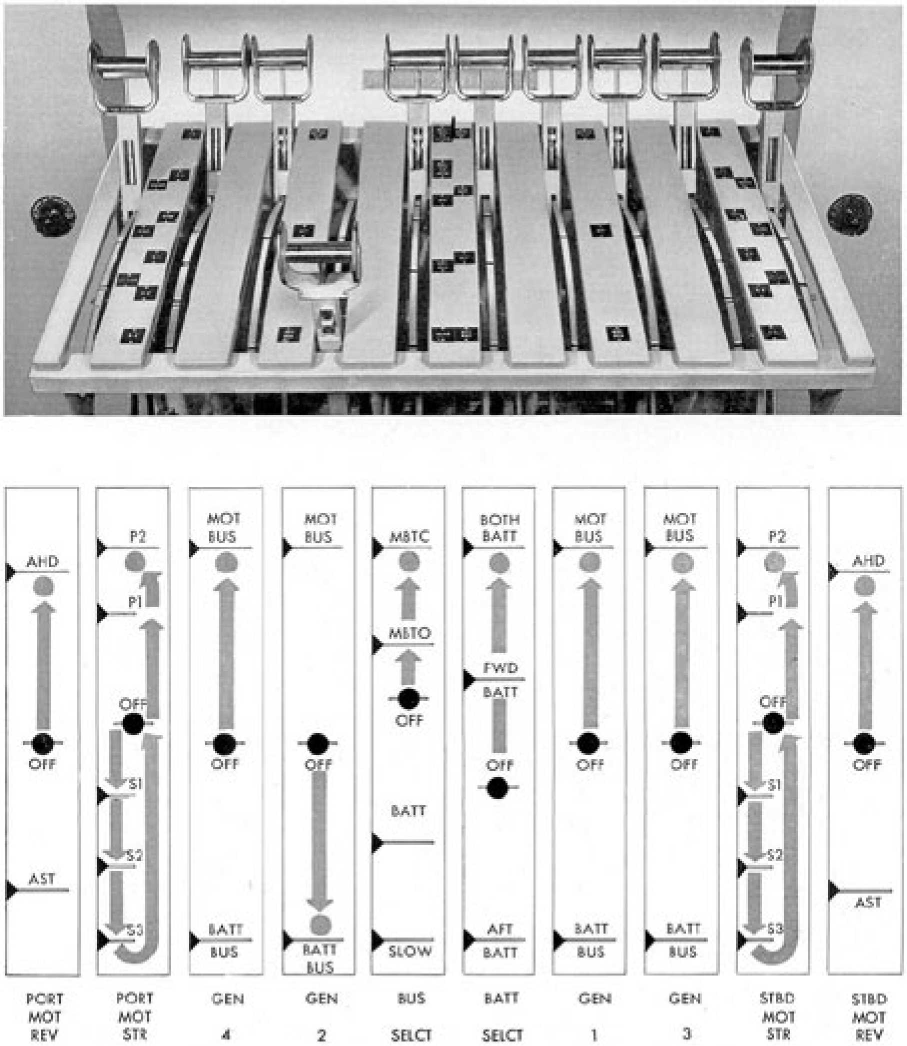

Figure 3-24. Position of operating levers when charging batteries with one generator and with the other generators supplying propulsion power.

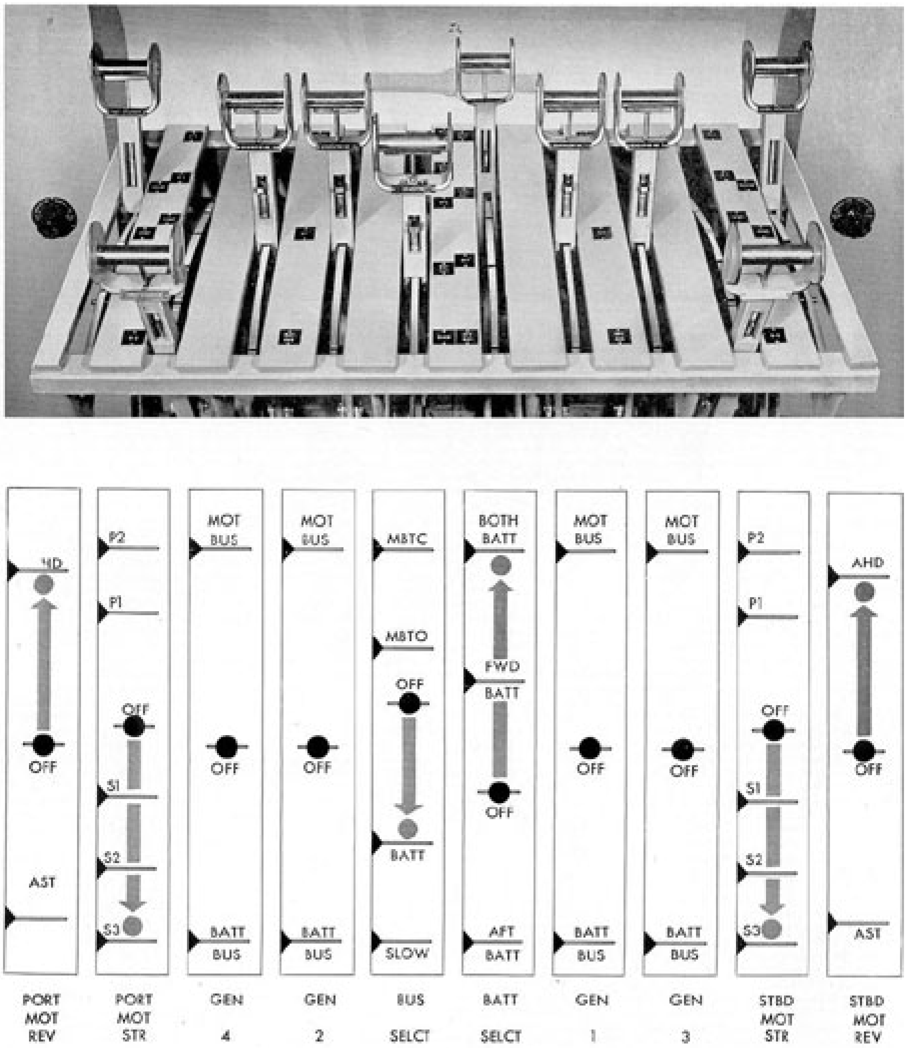

Figure 3-25. Position of operating levers for battery operation of 1/3 and 2/3 speed.

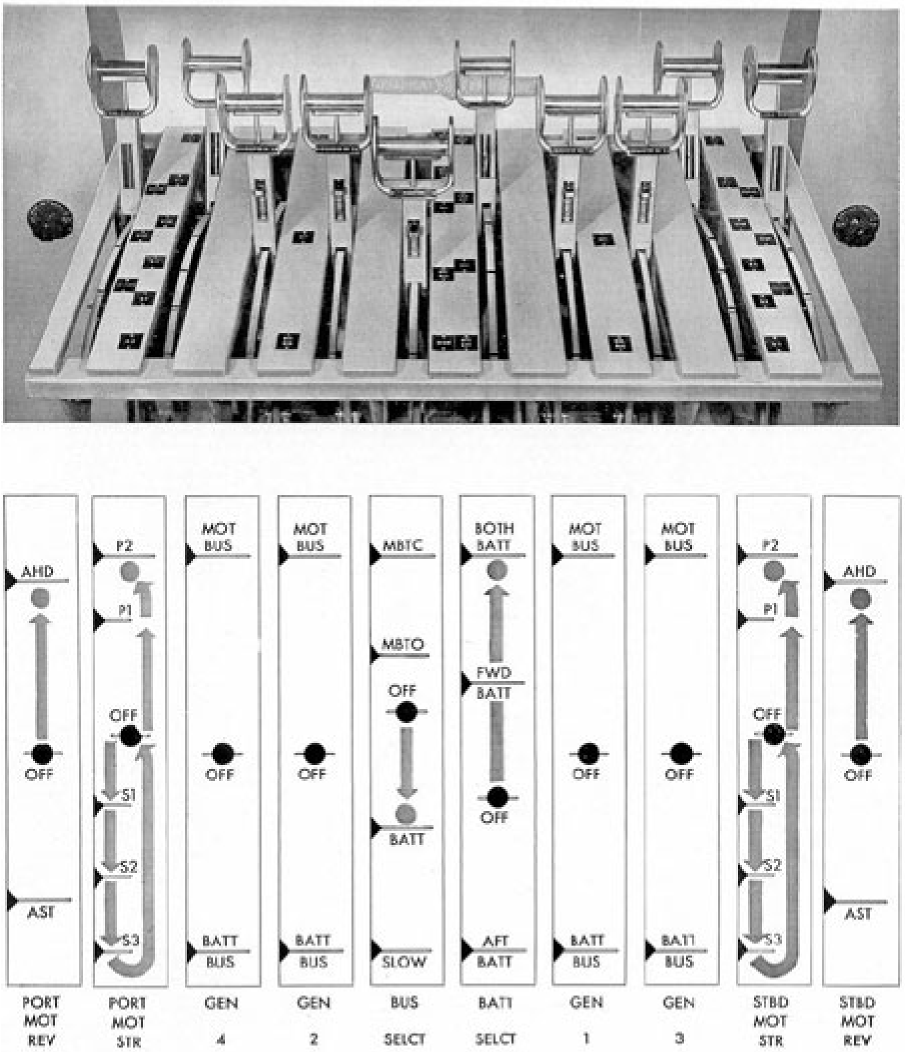

Figure 3-26. Position of operating levers for battery operation at standard and full speed.

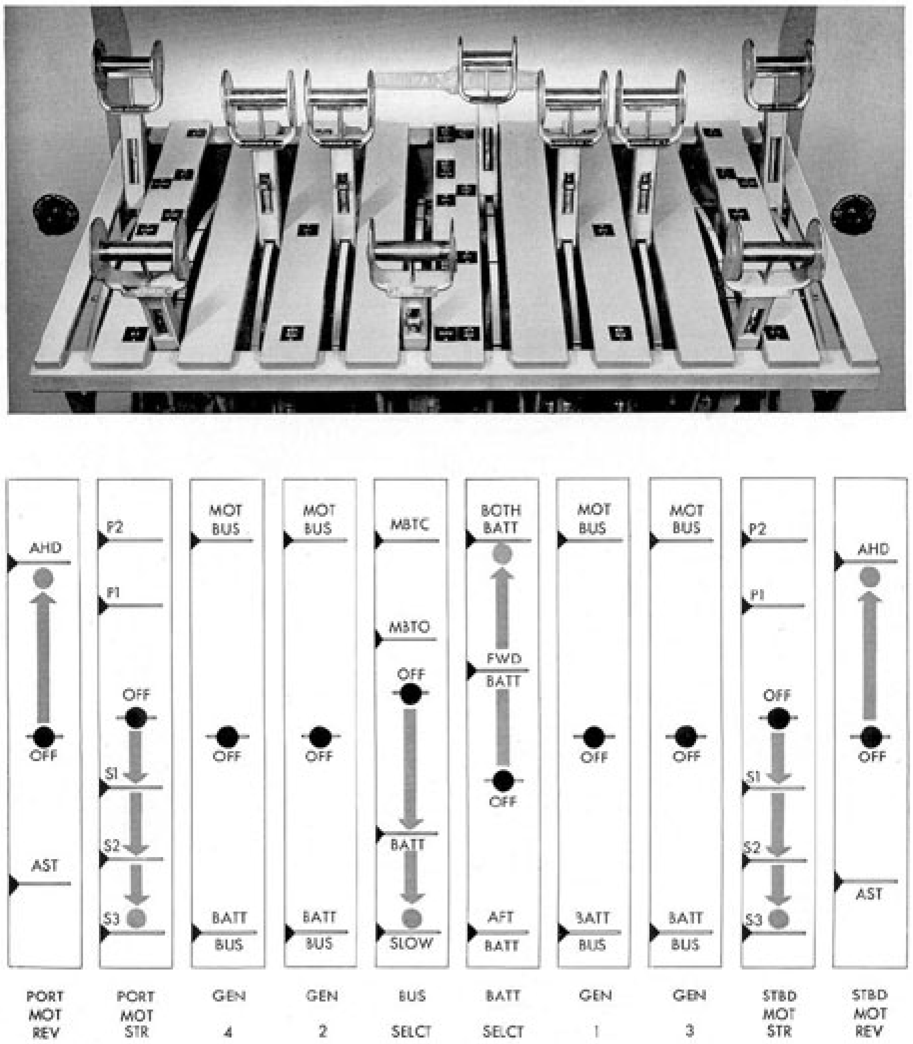

Figure 3-27. Position of operating levers for battery operation at slow speed.

3B11. Split type propulsion control. In general, the split type propulsion control is operated in the same manner as the unit type. Due to the duplication of bus selector and battery levers, both must be moved to the same position to operate with bus tie closed and in dead slow speed.

3B12. Safety precautions. The following are the more important safety precautions to be observed in handling this equipment:

1. Do not enter the main control cubicle when the buses are energized.

without first checking to see that its voltage is equal to the voltage of the bus.

5. If the lubricating oil pressure on the motors and reduction gears fails, stop the motors immediately and ascertain the cause of the failure.

6. Never release the control lever latches unless preparatory to moving to a new position. Make certain that a lever engages the slot in its new position.

7. Do not operate the machinery with the safety devices or interlocks disconnected.

2. Do not leave the motor and generator field circuits energized when the machines are not in service except for the purpose of keeping the machines from 5 degree to 10 degree F warmer than the surrounding air in order to prevent condensation of moisture on the windings. Even then the field current should never be more than is necessary for that purpose.

3. Do not operate the motors and generators with field currents in excess of the recommended values.

4. Never place a generator on a live bus

8. Do not advance the motor starting levers to the next position until the armature current has dropped to a reasonable value.

9. Make frequent inspections to insure that no tools or loose objects are inside the control cubicle or in such a position that they can fall into it or any part of the operating gear.

10. Whenever possible, deenergize the control cubicle and make frequent inspections for loose nuts and bolts and other connections.

11. Never operate the motors or generators at greater than rated armature current.

C. MAINTENANCE

3C1. Inspection and lubrication. The amount of servicing and replacement of parts of the control equipment depends upon the frequency of and care exercised in regular inspection. In normal service, the equipment should be inspected at approximately monthly intervals. Particular emphasis should be placed on keeping contacts, cams, and mechanism free from dirt and other foreign matter. Such parts as bolts, nuts, and screws should be checked for tightness. Bearing surfaces must be kept properly lubricated. A drop or two of oil applied on control linkages at the time of regular inspection will provide sufficient lubrication. Excessive lubrication is harmful; oil or grease should be used sparingly.

3C2. Contactors. It is essential that the contacts of all contactors, switches, and relays be kept clean. Arcing contacts and arc boxes that are badly burned should be cleaned or replaced. In an emergency, the are chute of a frequently operated working contactor may be interchanged with that of a contactor subjected to less arcing. When contact tips are found to be badly burned or making poor contact, they should be dressed with a fine file. Do not use emery or sandpaper. Contacts can be checked by laying a strip of carbon paper against a clean sheet of thin paper and inserting these strips between the contact surfaces. Closing the contacts will leave on the paper a carbon impression that will indicate the approximate condition of the contact surfaces (Figures 3-28 and 3-29).

Figure 3-28. Checking contacts with carbon paper.

Figure 3-29. Carbon impressions of contact surfaces.

3C3. Motor reverser and bus selector switches. The springs of the selector and reverser switches exert a pressure of several hundred pounds to hold the contacts together when the switch is thrown. The normal contact gap and wipe as specified by the manufacturer should be maintained within 1/64th of an inch. Installation conditions may reduce the tip wipe slightly, but the switch will operate successfully as long as a positive wipe is obtained.

Contacts should be examined to see that foreign material has not accumulated on the silver surfaces. Surfaces should be kept aligned so that a carbon paper impression will show that at least 60 percent of the contact area, well-distributed over the entire surface, is making contact. Use only a fine file for dressing the surfaces. These switches function only as circuit-selector switches and are never required to make or break their contacts with current flowing. The wear of the silver contact surfaces is therefore negligible and the contacts should require replacement only after long periods of service.

Since these switches are of double throw design, it is necessary that both the upper and lower contact gaps and wipes be equal. If they are not equal, and all switch units operated by a common camshaft show the same irregularity in the gap and wipe dimensions of the upper and lower contacts, the difficulty is probably caused by a loose cam or by slippage of the

moving contact assembly on the vertical supports. Contacts should not be shimmed to correct for irregular gaps or wipes.

3C4. Ground detection.A ground detector system is installed in the propulsion control cubicle to test for grounds on a number of circuits. It consists essentially of a zero-center ground detector voltmeter with selector switches so arranged that the voltmeter can first be connected from ground to the positive side of a circuit and then from ground to the negative side of the circuit. If the voltmeter reads zero in both cases the circuit is not grounded. If one side of the circuit has a dead, or very low resistance ground, the voltmeter will read zero when connected from ground to the grounded side, and will read full circuit voltage (voltage

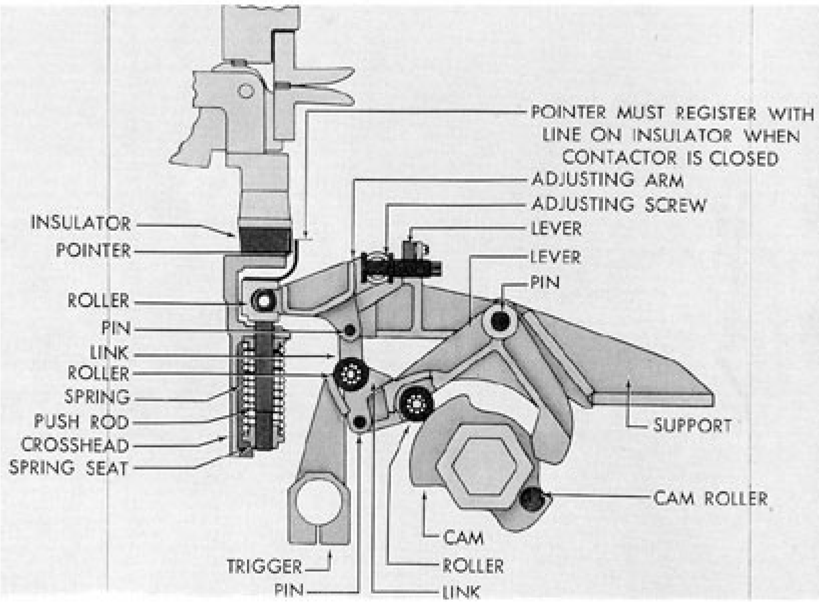

Figure 3-30. Operating mechanism of G.E. motor, generator, and battery contactors, CLOSED position.

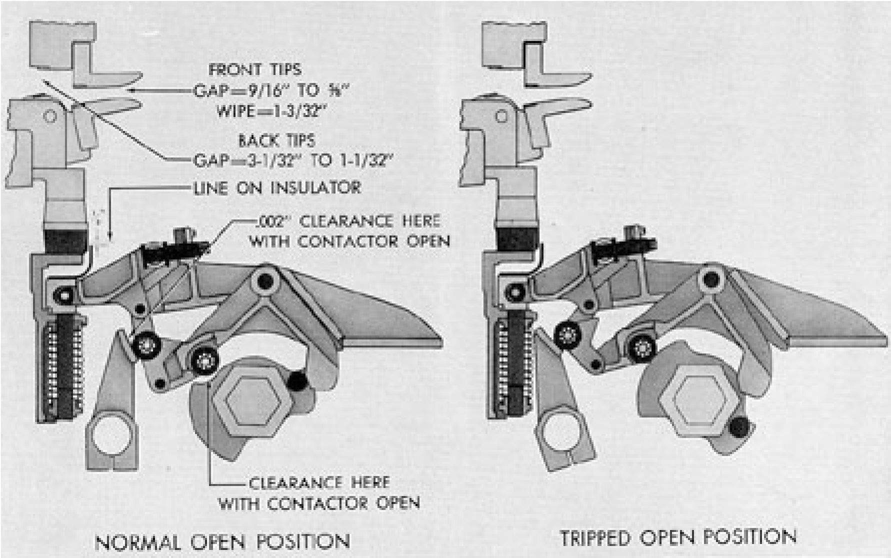

Figure 3-31. Operating mechanism of G.E. motor, generator, and battery contactors, OPEN position.

from positive to negative side) when connected from ground to the ungrounded side of the circuit. If the ground has an appreciable resistance or if it occurs at a point on the circuit where the potential is intermediate between the potentials of positive and negative sides of the circuit, the ground detector voltmeter readings will be less than full circuit voltage. The ground detector system can be used to detect grounds on the battery or machines while they are in operation, and on machines while they are idle.

a. Battery grounds. 1. To detect battery grounds, turn the machinery ground detector selector switch to OFF. A study of Figure 3-32 shows that the battery selector switch can be used to connect the ground detector voltmeter to each battery in each of the following ways:

c) From ground to the center point joining two equal high resistances connected in series across the positive and negative battery terminals. The potential at the center point between the two resistances is obviously the same as the potential at the center point of the battery.

2. When connected according to c) above, the voltmeter will deflect in one direction for a ground or grounds on the positive cable leg or positive half of the battery; and in the opposite direction for grounds on the other half of the system. There will be no deflection of the voltmeter if the battery is grounded at the center; or if the battery and cables are symmetrically grounded on both sides of the center; or even if the system is unsymmetrically grounded on both sides of the center if certain relations exist between the positions of the grounds and their resistances. Consequently, when the voltmeter is connected to the battery in this

a) From ground to positive battery terminal.

b) From ground to negative battery terminal.

way, a voltmeter deflection definitely establishes the

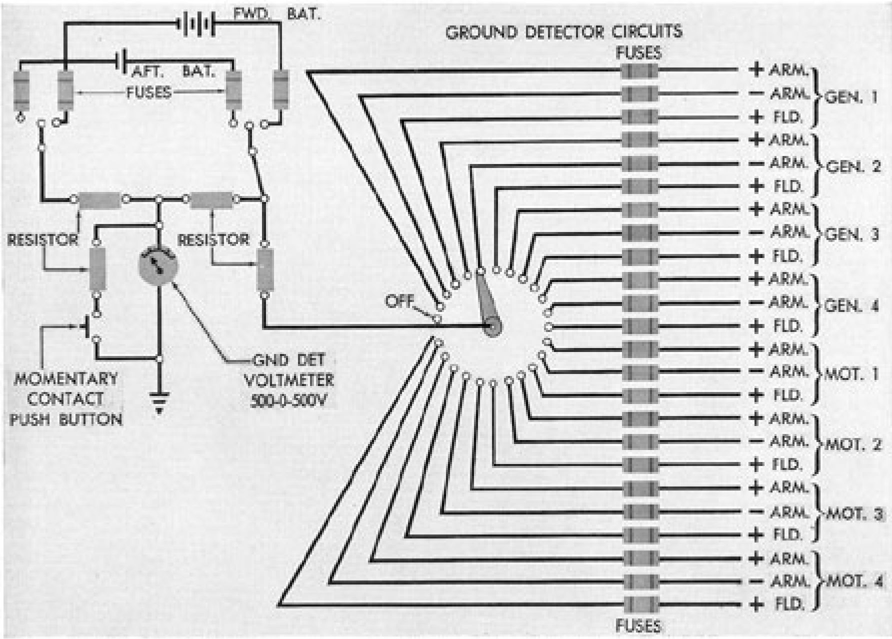

Figure 3-32. Ground defector wiring diagram.

existence of a ground on the battery or cables, but the absence of a deflection furnishes no assurance that grounds are absent.

3. A conclusive test for the presence or absence of grounds is made by noting V_p, the voltmeter reading when connected to the positive battery terminal, and V_n, the voltmeter reading when connected to the negative battery terminal. These are the ground detector voltmeter readings when it is connected according to a) and b) above. If both V_p and V_n are equal to zero, there are no grounds. If either is different from zero, or if both are different from zero, there is at least one ground on the battery or on

connects the ground detector voltmeter from ground to the center point between the two resistances. There may be a small deflection of the voltmeter if the battery and its circuits have a high resistance ground or grounds, or there may be no deflection. The test on machinery can be made in either case. To do this, turn the machinery selector switch from OFF to the machine or circuit which is to be tested. If the ground detector voltmeter reads the same as it did when the selector switch was at OFF, neither side of the machine or circuit tested is grounded. If the reading is not the same there is a ground.

CAUTION. Always turn all ground detector selector switches to OFF when testing has been completed. Furthermore, never attempt to use more than one ground detector

cables or equipment connected to the battery.

a. On the newer submarines, grounds on the battery alone, when disconnected from its cables by opening the battery disconnect switches (main and auxiliary power and emergency lights) in the battery tank, can be detected and measured by using the voltmeter mounted on the individual cell voltmeter panel (see Section 5A9).

b. Test on machines in operation. To detect grounds on machines in operation, turn the ground detector battery selector switch to OFF, or in some installations to TEST LIVE CIRCUIT. Turn the machinery selector switch to connect the ground detector voltmeter from ground, first to one side of the machine and then to the other side. If the ground detector reads zero in both cases, there are no grounds. If either reading is different from zero, or if both are, there is a ground on the machine or in the circuit to which it is connected. It may be noted in Figure 3-32 that the ground detector voltmeter can be connected to either the positive or the negative side of the armatures, but to only one side of the field circuits. A zero reading on one side of a field circuit is not sufficient to show that no part of the circuit is grounded, but further test on the machine when it is idle will check this point.

c. Test on machines when idle. To make a test on machines that are idle, first turn the machinery selector switch to OFF, then turn system at a time. There are several installed but they should be used one at a time.

3C5. Use of ground detector voltmeter to measure insulation resistance. A megger is not suitable for measuring the resistance of battery grounds because a battery, unlike a generator, cannot be deenergized. The ground detector voltmeter system, however, can be used not only to detect grounds but also to measure the insulation resistance to ground from batteries or from energized equipment or circuits. The insulation resistance to ground is found by using the equation:

$R = R_v ((E/(V_p - V_n) - 1)$

In this equation, E represents the voltage across either a motor, generator, or battery as the case may be; V_p and V_n represent the reading of the ground detector voltmeter when connected to the positive and negative terminals of the motor, generator, or battery; R_v is always the resistance of the ground detector voltmeter.

Consider, for example, a submarine with a 50,000-ohm ground detector voltmeter on the submarine control cubicle. With the battery connected to the control cubicle, the battery voltage E was observed to be 243 volts, and the readings of the ground detector voltmeter were from each leg to ground V_p = 10, and V_n = 192. The insulation resistance to ground from the complete circuit including the battery and

the battery ground detector selector switch to TEST DEAD CIRCUIT. This connects two high resistances in series across one battery and

the cables from the battery to the control cubicle was therefore:

R = 50,000 ((243/202) - 1) = 10,000 ohms

This was a low value of insulation resistance and required further investigation. The battery was isolated from the cables by opening the battery disconnect switches, and additional measurements were made on the battery alone by using the ground detector voltmeter on the individual cell voltmeter panel. The ground detector voltmeter installed on this panel had a resistance of 30,000 ohms. The battery voltage E was 243 volts, while V_p and V_n were 9.2 and 10.6 volts respectively. The insulation resistance to ground from the battery alone was, therefore:

R = 30,000 ((243/19.8) - 1) = 338,000 ohms

The cause of the low resistance observed at the control cubicle was, therefore, not the battery, but the battery cables. Tests made on these with a megger showed that one leg had a low resistance and this was responsible for the low resistance found for the complete circuit. Similarly, by use of the above formula, resistance to ground of any generator or be remembered that measurements by this method while machinery is energized and operating represent the combined resistance to ground of all machinery connected to the same circuit. Whenever a low value is obtained, the units must be completely isolated and individual readings taken of insulation on each component in order to locate the affected part.

The accuracy obtained in measuring insulation resistance with a ground detector voltmeter depends upon the accuracy and resistance of the voltmeter used and the value of the insulation resistance being measured. Insulation resistances that are either very large or very small as compared to the voltmeter resistance are determined only approximately. Insulation resistances not too greatly different from the voltmeter resistance can be measured with considerable accuracy.

Very accurate measurements of insulation resistance can be made when needed by deenergizing the circuit and using an insulation resistance tester. The chief advantages of the ground detector voltmeter are that it can be used to measure insulation resistance at any time a circuit is in use, and that it furnishes a means of

motor may be measured while it is operating. It must making a continuous check on insulation resistance.

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Figure 4-1. DIAGRAM OF AUXILIARY POWER CIRCUITS.

4
AUXILIARY POWER CIRCUITS MOTORS, AND CONTROLS

A. GENERAL

4A1. Description. Approximately 50 auxiliary motors of various capacities are located throughout the ship for operation of compressors, blowers, pumps, and other miscellaneous equipment. Current for operation of these motors is supplied by the auxiliary generator, the main batteries, or a combination of both, through two auxiliary distribution switchboards. The forward distribution switchboard, connected to the forward battery, feeds all auxiliary machines in and forward of the control room, while the after distribution switchboard, powered by the after battery or the auxiliary generator, feeds all auxiliary machines aft of the control room. A bus-tie circuit connects the two switchboards, making it possible to feed one switchboard from the other in an emergency.

During normal operation, the bus-tie circuit is left open and the power for both switchboards is taken from the batteries, with the auxiliary generator often floating on the line. The batteries are connected in parallel through the battery selector in the main control cubicle. With the circuit so connected, the auxiliary generator contributes current not used by the auxiliary load toward charging the batteries. This circuit arrangement is also used when the auxiliary generator is secured.

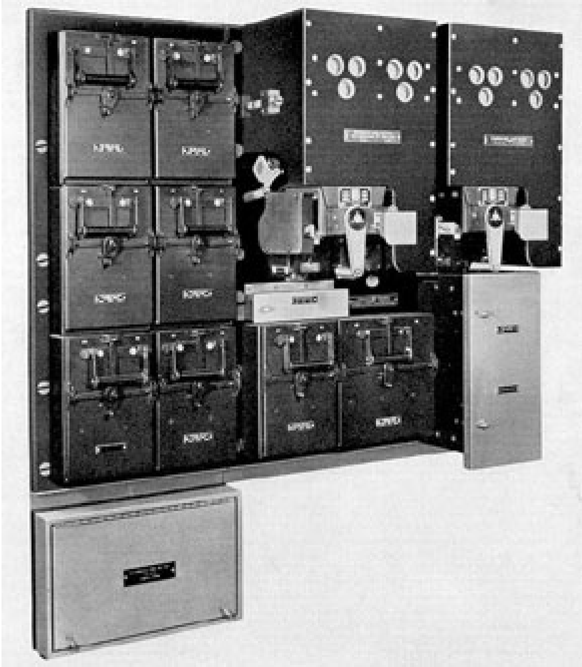


Figure 4-2. Forward auxiliary power switchboard.

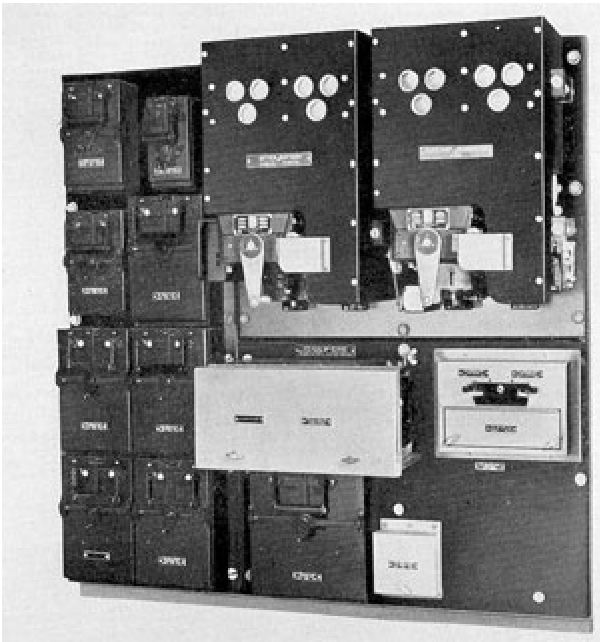


Figure 4-3. After auxiliary power switchboard.

4A2. Shore connection. The bus-tie circuit is equipped with terminals to which an outside source of power, such as a shore connection or tender, can be connected for operation of the auxiliary circuits. The procedure to be followed in connecting the shore cables for operation of the auxiliary circuits is as follows:

1. Make certain that both bus-tie switches are open.

external source through both auxiliary power switchboards.

To connect shore cables for charging the batteries, proceed as follows:

1. Place the battery selector lever in the main control cubicle in the OFF position.

2. Check the polarity of the external power supply.

2. Check the polarity of the 250-volt external power supply.

3. Connect the positive lead to the positive terminal of the shore connection block and the negative lead to the negative terminal of the shore connection and energize the circuit.

4. Trip the auxiliary board battery breakers and close the bus-tie switches on both auxiliary power switchboards.

5. Current is now available from the

3. Bring the shore cables down through the after engine room hatch.

4. Connect the positive lead to the positive terminal and the negative lead to the negative terminal on the battery bus in the control cubicle.

5. To charge both batteries, move the battery selector lever to the BOTH BAT. position.

6. To charge a battery separately, place the battery selector lever on FORWARD BATTERY or AFTER BATTERY position.

B. AUXILIARY MOTORS

4B1. Description. Auxiliary motors are direct current motors designed to operate on a voltage ranging from 175 volts to 345 volts. Their horsepower rating, type of winding, and other data are given on the name plate attached to each motor. Auxiliary motor frames are enclosed to provide protection against dripping water and are vented to permit the escape of

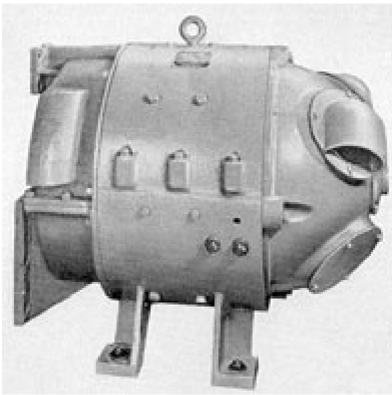


Figure 4-6. D.C. motor for high-pressure air compressor.

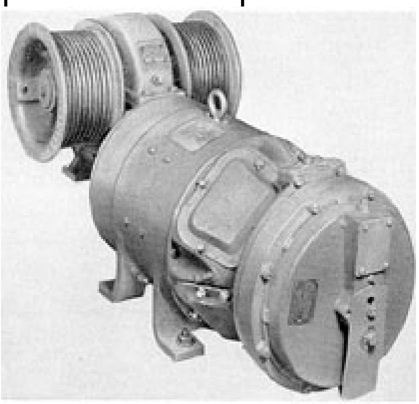


Figure 4-4. D.C. motor for antenna and periscope hoist, equipped with magnetic disk brake.

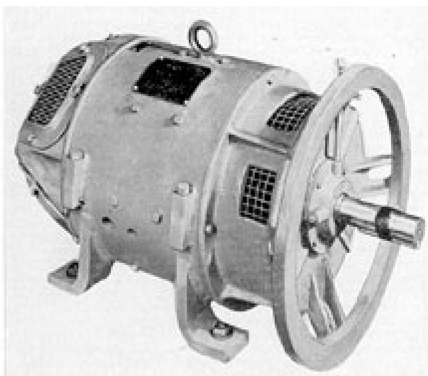


Figure 4-7. D.C. motor for hull ventilation supply fan.

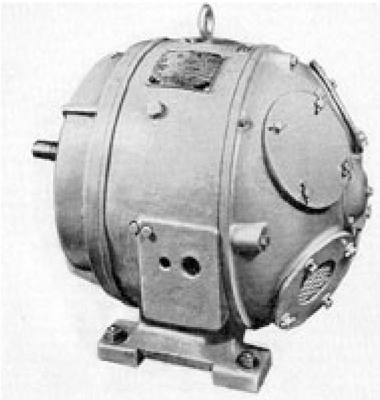


Figure 4-5. D.C. motor for air-conditioning compressor.

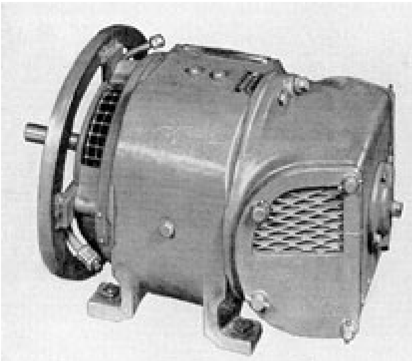


Figure 4-8. D.C. motor for battery ventilation fan.

hot air which is forced out by a fan attached to the armature shaft. Magnetic disk brakes are used on motors which must stop after the current is shut off (see Section 4E1). A few of the various types of auxiliary motors are shown in Figures 4-4 through 4-10. Their electrical and mechanical details are similar to those of the main generators and motors.

Figure 4-9. D.C. motor for drain pump.

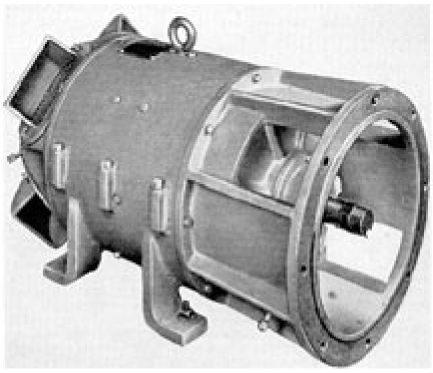


Figure 4-10. D.C. motor for trim pump.

C. MOTOR GENERATOR SETS

4C1. Description. There are two types of motor generator sets, lighting motor generator sets and I.C. (interior communication) motor generator sets.

a. Lighting motor generator sets. These machines are used on some ships to deliver current for the operation of the lighting system as well as for the I.C. motor generator sets which require a lower voltage than that delivered directly by the battery or auxiliary generator. The 175- to 345-volt d.c. motor receives its power from the battery or auxiliary generator and through a common shaft drives the 120-volt generator. It is controlled by a speed regulator similar to that described in Section 9A1 for the I.C. motor generator sets.

NOTE. On some ships lighting motor generator sets have been superseded by lighting feeder voltage regulators (see Section 6D1).

b. I.C. motor generator sets. I.C. motor generator sets are d.c.-a.c. machines equipped with speed and voltage regulators to produce a 60-cycle current for interior communication, radio, radar, and sonar systems. The d.c. motor receives its power from the lighting motor generator on some ships, or directly from the battery or auxiliary generator on others.

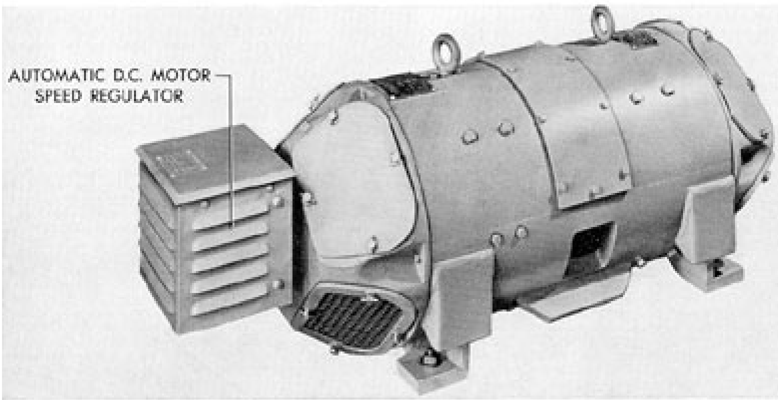


Figure 4-11. Motor generator set.

D. CONTROL EQUIPMENT

4D1. Magnetic contactor starting panels. Most of the auxiliary motors are controlled through a magnetic contactor starting panel with push-button control for starting and stopping the motor.

The push-button station may be located some distance away from the motor in which case an indicating light in the push-button case will signify that the When the ON button is pressed, the coil of the main contactor is energized, causing the contactor to close and thus connect the motor to the line through two or three steps of resistance. The number of steps of resistance used depends upon the size, capacity, and duty load of the motor.

Acceleration is controlled by the action of adjustable series relays. When the inrush current decreases

motor is running. This light is connected across the motor armature, or through an auxiliary contactor in the starting panel and will burn at maximum brightness only after the last step of starting resistance has been cut out of the motor circuit.

to the value for which the relays are adjusted, the contacts of the first series relay close and energize the coil of the first accelerating contactor. This contactor closes and shorts out the first resistor step. When the second

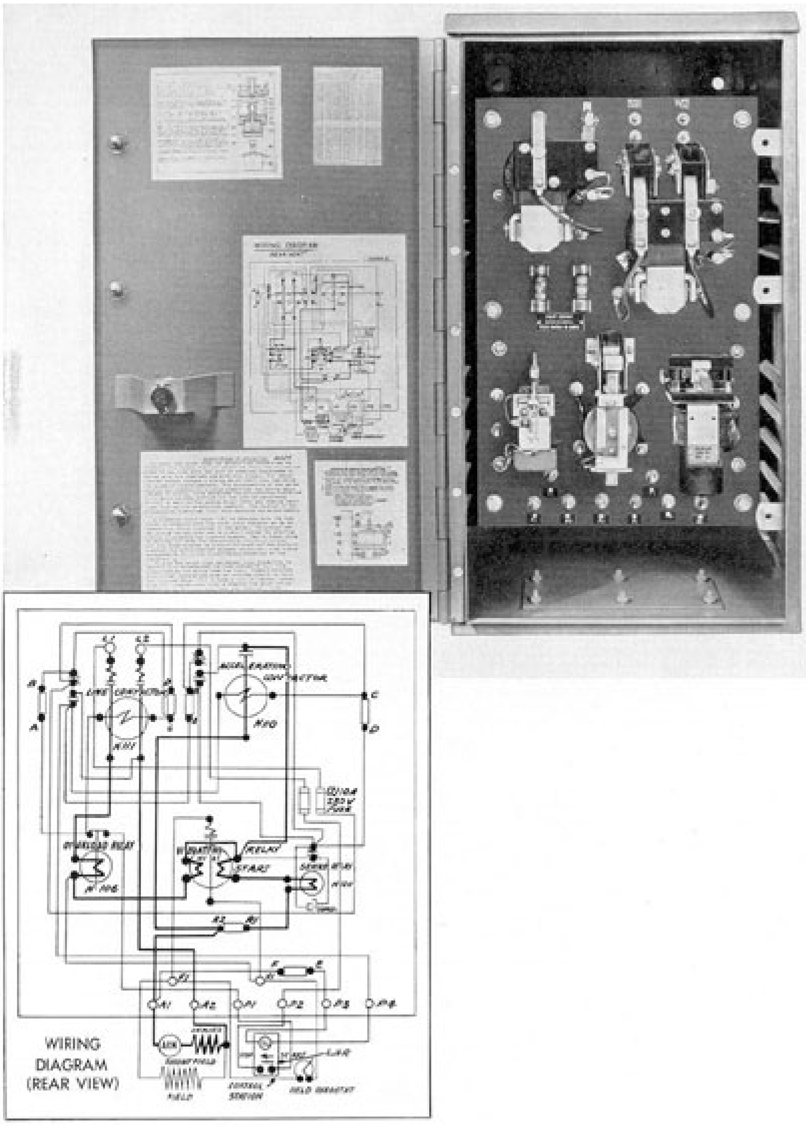


Figure 4-12. Magnetic contactor starting panel.

in-rush of current decreases to the amperage for which the relays are adjusted, the contacts of the last series relay close. The last accelerating contactor then closes and shorts out the second reaching its upward limit and opening the contacts in approximately 1 1/2 to 2 seconds.

Thermal overload relays used in some controllers consist of a heater coil, solder tube, control

resistor step and places the motor across the line.

NOTE. On controllers of Westinghouse manufacture, acceleration is controlled by fixed time delay relays instead of current relays.

The operation of the controller is subject at all times to the operation of an overload relay which opens the circuit to the main contactor on excessive overloads.

Some overload relays are provided with a time delay mechanism which allows a momentary overload. The time lag is produced by an oil dashpot. When the current taken by the motor rises to approximately 175 per cent of full load current, a plunger is drawn forcibly upward against the action of the dashpot, contacts, ratchet mechanism, and compression spring. Under normal conditions, the contacts of the relay are closed. The spring is then under compression and tends to open the contacts, but is prevented from opening them, however, by the outer part of the solder tube holding the ratchet mechanism. When the current to the heater coil becomes great enough to melt the solder holding the outer part of the tube, this part of the tube rotates and releases the ratchet mechanism to open the control contacts. The opening of these contacts breaks the circuit to the coil of the contactor handling the power circuit and this circuit is opened. As soon as the power circuit is opened, the solder film cools and hardens, and the relay is ready to be reset by means of the reset button.

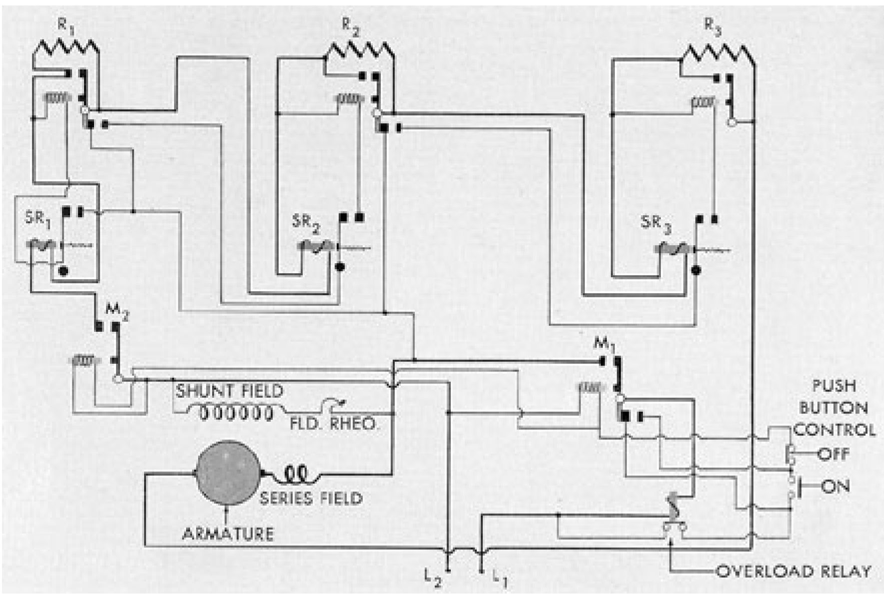


Figure 4-13. Simplified schematic diagram of automatic motor starter.

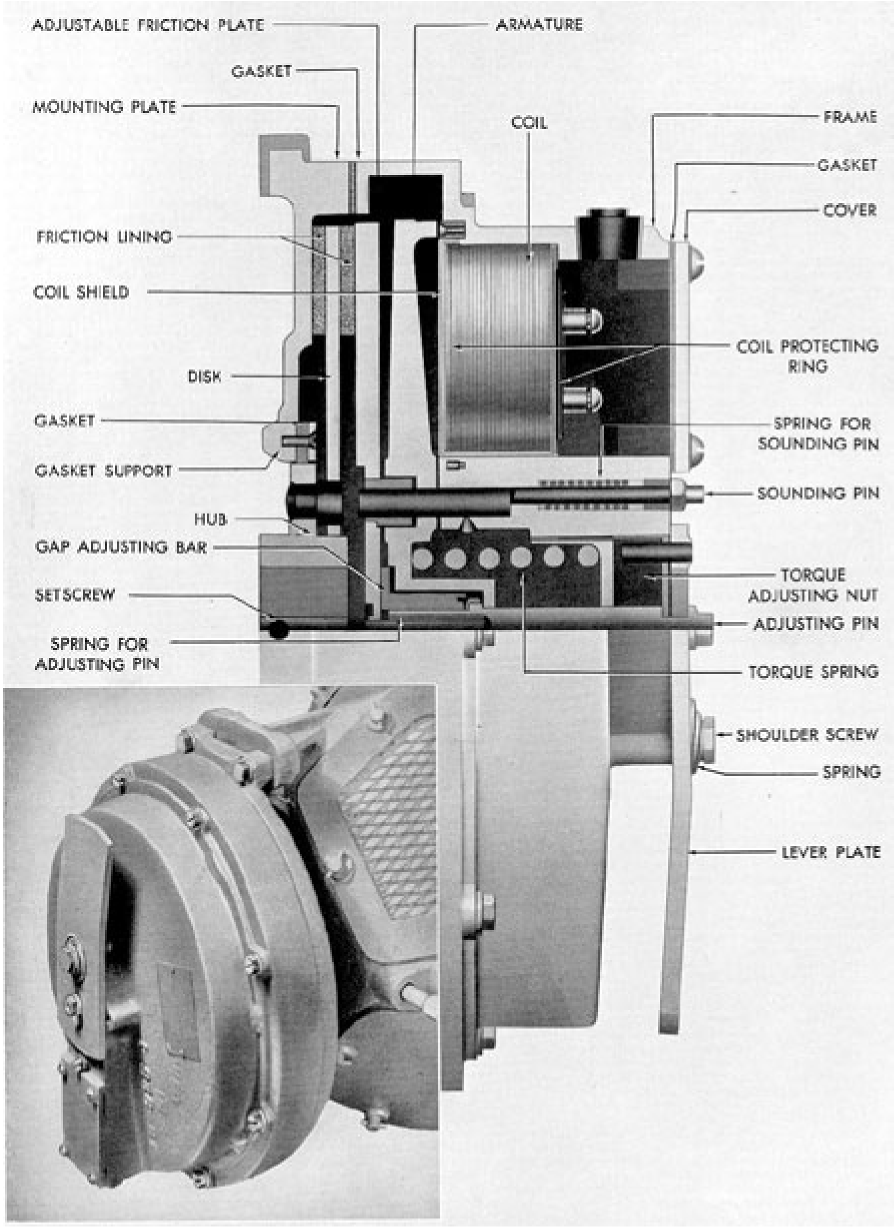


Figure 4-14. Magnetic disk brake.

E. MAGNETIC BRAKES

4E1. Description and operation. Magnetic disk brakes are used on the following auxiliary motors for stopping the rotation of the armature after the current has been shut off: periscope and vertical antenna hoist, bow plane tilting, stern plane tilting, after capstan, anchor windlass, bow capstan, bow plane rigging, and steering gear.

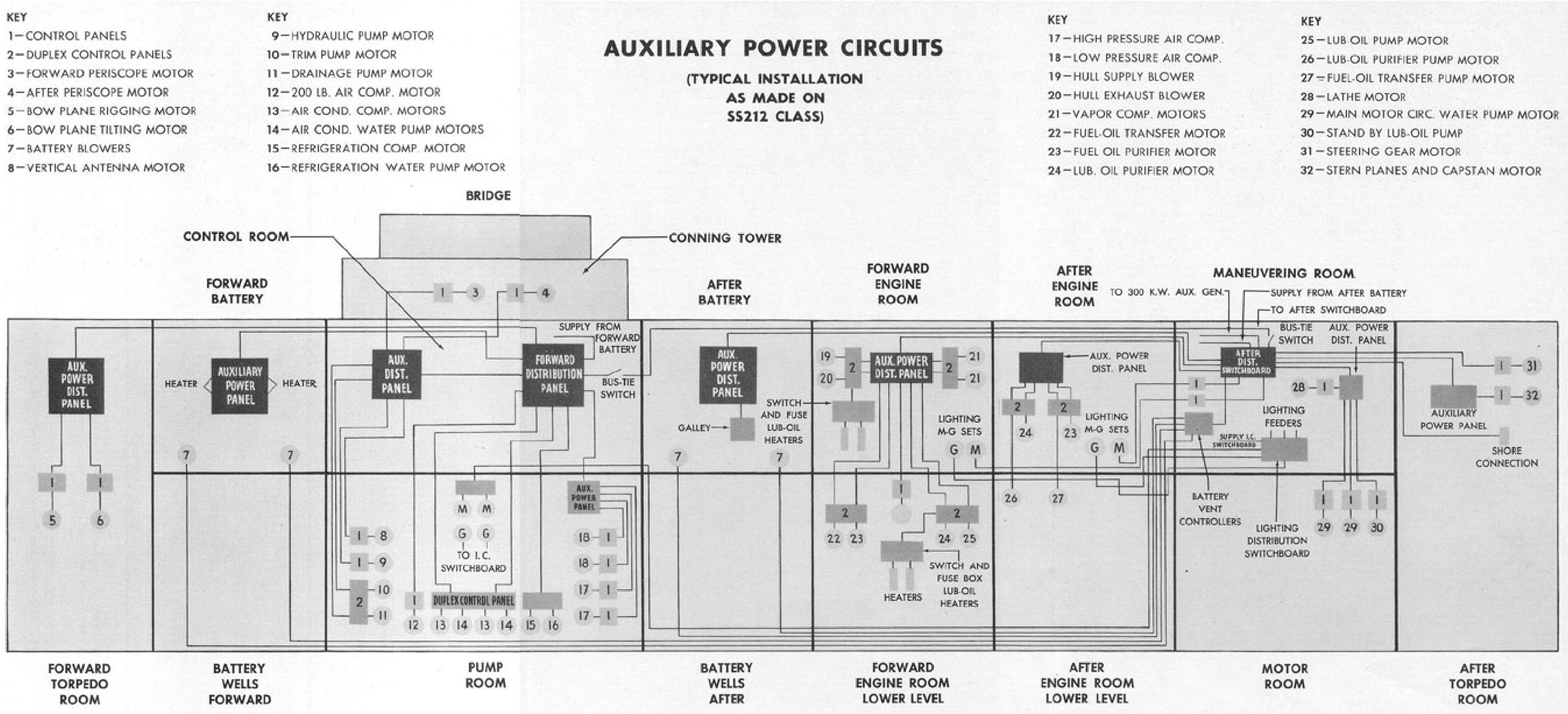
and the adjustable friction plate toward the field when the coil is energized. This provides clearance between the friction faces and allows the motor shaft to turn freely. When the coil is not energized, the brake can be released by hand by pulling a lever plate axially away from the brake magnet. When the lever is released, the brake resets itself.

The hub of the brake is keyed on each side and is attached to the hub so that there is no relative rotation, but so that the disk may move axially on the hub. The exposed friction lined face engages with the stationary friction face on the mounting plate through pressure of a spring. The amount of pressure and the resulting torque can be adjusted by changing the spring compression. The field, armature, and coil constitute an electromagnet which overcomes the spring force and moves the armature

4E2. Magnetic gap adjustment. With the magnet deenergized, measure the amount the sounding pin can be pushed in. Make a similar measurement with the magnet energized. The difference between the two measurements is the magnetic gap. As the linings wear, the magnetic gap increases. When the gap approaches the maximum allowable limit as specified by the manufacturer, it must be readjusted. Refer to the manufacturer's instruction book for specific data and adjustment procedures.

Figure 4-1. DIAGRAM OF AUXILIARY POWER CIRCUITS.

Sub Elec. Home Page



5
MAIN STORAGE BATTERIES

A. DESCRIPTION

5A1. General. Each ship has 2 main storage batteries consisting of 2 groups of 126 cells each. The forward battery is installed beneath the wardroom country and the after battery is located under the crew's quarters.

5A2. Data. The physical dimensions of an individual cell are approximately as follows:

Bottom of jar to top of filling vent cap	54 in. (approx.)
Depth	15 in. (approx.)
Width	21 in. (approx.)

The weight of one cell ready for service is approximately 1650 pounds without intercell connectors or vent ducts.

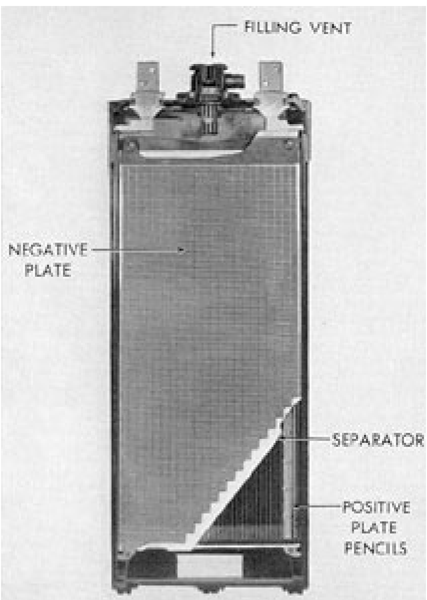


Figure 5-1. Cutaway of Exide

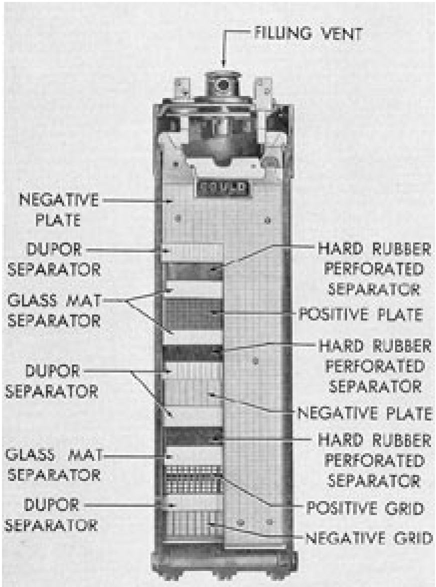


Figure 5-2. Cutaway of Gould storage battery cell.

6A3. Wedging. The battery tanks are divided into 4 sections by 3 steel cross tie plates athwartships which serve to add structural strength to the hull. The battery cells are held in position between these cross tie plates and between the longitudinal bulkheads by means of wooden wedges.

5A4. Strongbacks. The outboard rows and second rows of cells in each battery are provided with steel strongbacks which are held near the upper ends of these cells (approximately 2 in. below the cell tops) by means of bolts that pass through the upper ends of the wedges involved.

storage battery cell.

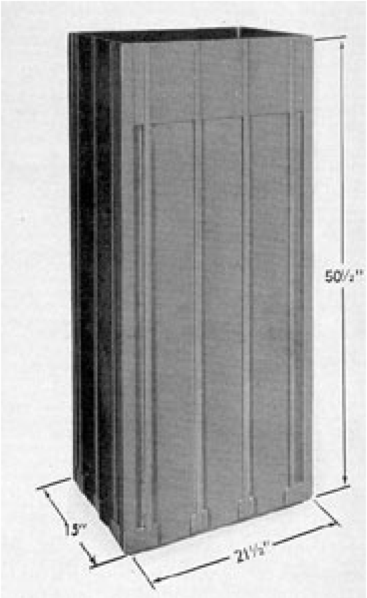


Figure 5-3. Battery cell jar.

5A5. Battery installation. The installation in each battery tank (see Figure 5-4) consists of 6 fore and aft rows of 21 cells each. The 2 center rows are on the same level. The rows alongside the center are slightly higher and the outboard rows are the highest. Above the 2 central rows of cells are installed panels of hard rubber which serve as a working deck or flat.

All cells are connected in series by means of intercell connectors while end cells in each row of batteries are connected by means of end-cell connectors. An ammeter shunt is connected to a bus bar that is attached to the No. 1 cell positive terminal post. Cables connected to the ammeter shunt run to the positive disconnect switch and thence to the main control cubicle. The cables from the negative (after port) side of the battery are connected to the end connector of cell No. 126. They disconnect switches are manually operated from a station at the after end of the forward battery room.

The after battery disconnect switches, also manually operated, are located near the after end of the crew's quarters. These disconnect switches are used only to isolate the battery from the cables and should never be opened under load except in an emergency. In some classes of submarines they are fitted with arc chutes and remote tripping devices.

Auxiliary power to the forward distribution switchboard and the after distribution switchboard is supplied through cables and knife switches which are connected to the battery side of the battery disconnect switches of their respective batteries. Distilled water for battery replenishing is carried in 8 tanks, located 2 on each side of the forward and after battery. The total capacity of the tanks is approximately 1200 gallons. Water outlets in each battery compartment are fitted with purifiers called ion-exchangers.

5A6. Battery ventilation. Each battery is fitted with an exhaust ventilating system to remove battery gases. The air required to operate this system is supplied through inlets located at opposite ends of each battery well. The free air in the compartment is drawn through the filling vent connection of each cell. The cells are

run to the negative disconnect switch and from there to the main control cubicle.

Both positive and negative forward battery

connected by soft rubber nipples to exhaust headers of hard rubber which extend fore and aft for each row of cells.

The headers are in 2 sections and are connected to cross headers which unite in a common exhaust duct. The exhaust duct from each battery is led up to and through the deck to the inlets of 2 fans that are mounted on the hull overhead in the respective battery rooms. Each of these 4 fans is rated at 500 cubic feet per minute at 2789 rpm. Each fan is independently driven and the motor is controlled from the maneuvering room. The motors used on late type submarines are rated at 1.25 hp (continuous), 2780 rpm, 175 to 345 volts, 5.0 amperes, and are compound wound.

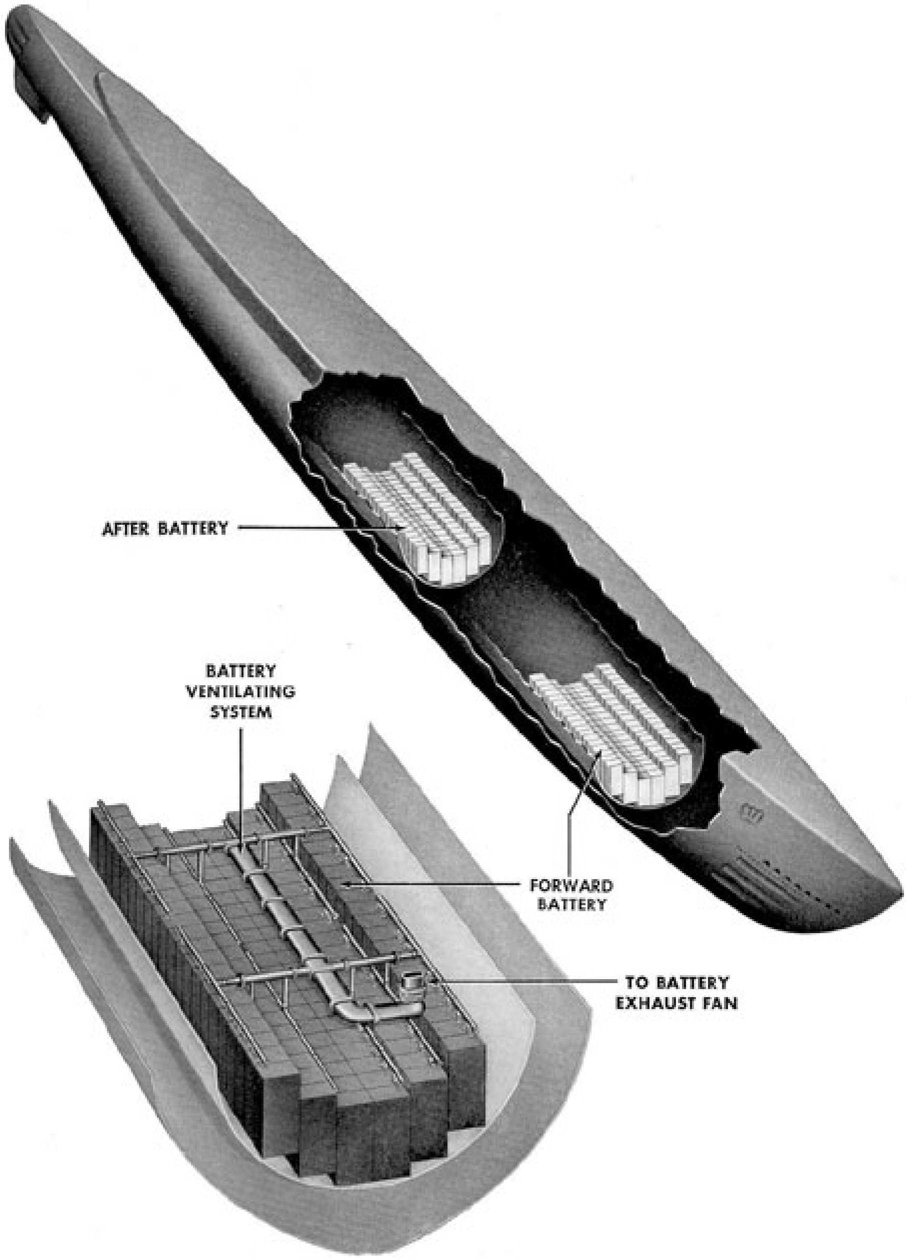


Figure 5-4. Battery installation.

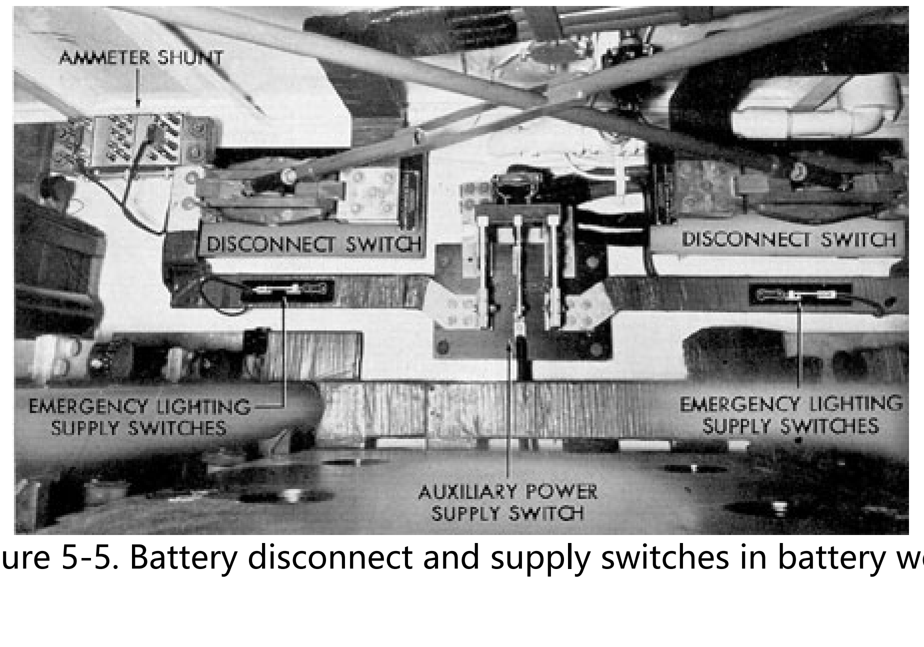


Figure 5-5. Battery disconnect and supply switches in battery well.

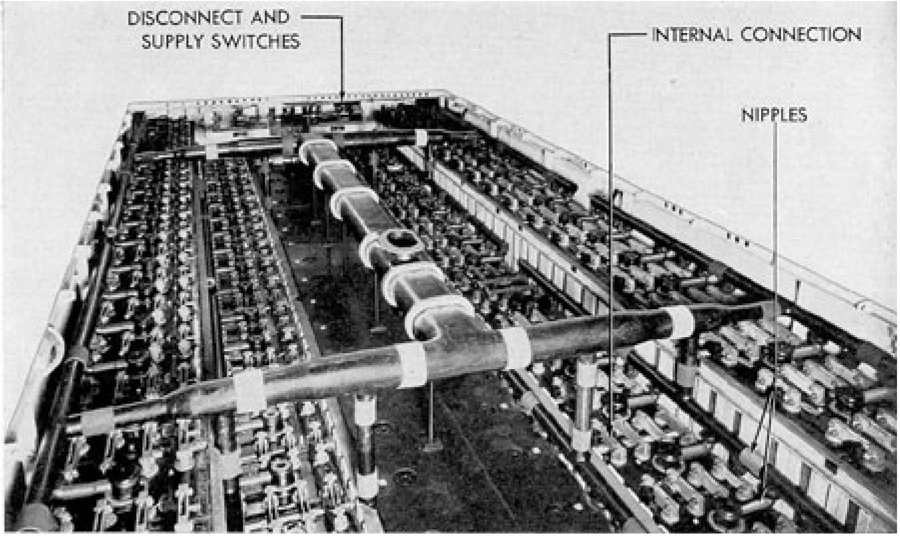


Figure 5-6. Battery ventilation ducts and cell connectors.

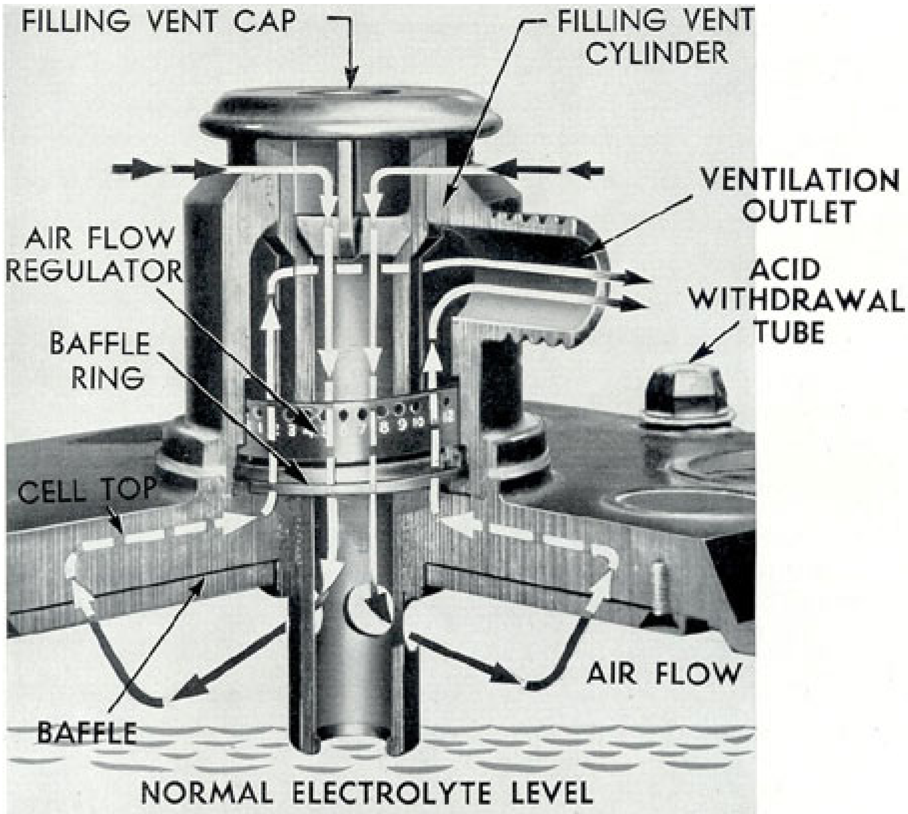


Figure 5-7. Cutaway of battery cell top.

Starting and speed regulation are accomplished by armature resistance. A fused tumbler switch for each motor is mounted in a separate case and connects both the armature circuit and the field circuit to the supply lines. Each armature circuit includes armature resistance, sections of which may be short circuited by a 20-point dial switch to provide speed switch marked BATTERY VENTILATION on the after distribution switchboard in the maneuvering room.

A damper is provided in the duct between the inlets of the 2 fans to allow the fans to be operated singly or together. When a single fan is used, the damper must be set so as to close the inlet to the idle fan, thereby preventing free

control. In regulating the battery ventilation by means of armature resistance adjustment, care must be taken (when 2 blowers are being used for a single battery) to set the pointers on both rheostat knobs to approximately the same point. The power supply is obtained through a fused circulation of air through both fans. Each pair of fans exhausts into the ship's exhaust line.

5A7. Air flow indicators. An indication of the quantity of air passing through the ventilation system is given in the maneuvering room

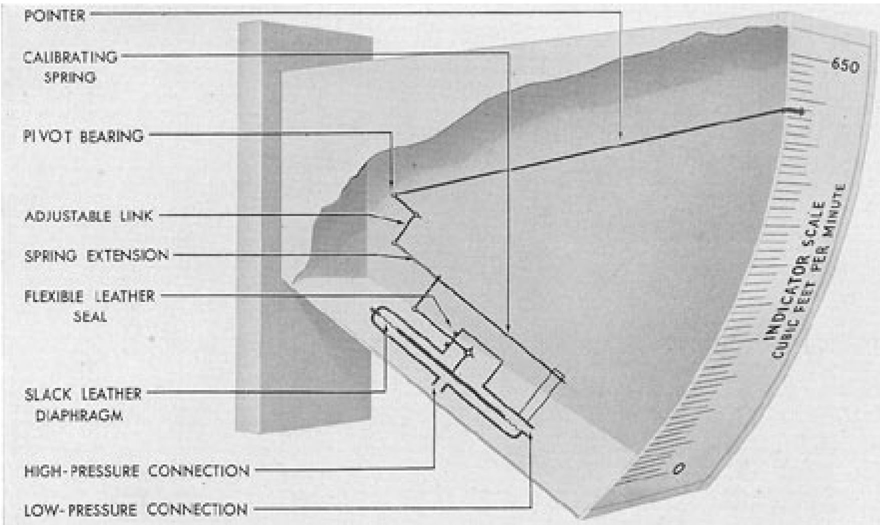


Figure 5-8. Battery ventilation air flow indicator, Hays type.

by means of 2 air flow indicators. Each of these indicators is provided with a scale marked in cubic feet per minute (Figure 5-8). Air flow meters are nonelectric and operate on a difference-of-pressure principle.

The ends of 2 copper tubes are inserted in the air stream of the battery ventilation exhaust line, one tube above, and the other below a hard rubber baffle.

The tubes are then led to the air flow meter. The difference in pressure between the tubes is measured by the instrument and indicated on a scale in cubic feet per minute of air flow. The operating unit of the meter consists of a slack leather diaphragm and a cantilever

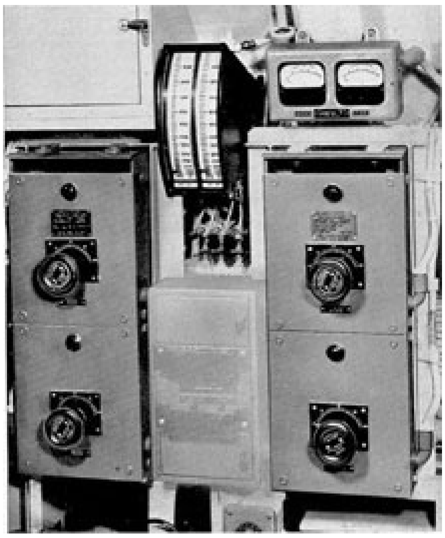


Figure 5-9. Battery ventilation motor controllers, ventilation flow meters, and remote hydrogen detector indicators.

spring attached to the scale pointer. The high-pressure copper tube terminates under the diaphragm and the low-pressure tube enters above the diaphragm. Difference in pressure determines diaphragm position and pointer indication.

Due to the delicate nature of the diaphragm,

the instrument must not be subjected to excessive pressures while in use or when being cleaned or calibrated.

The zero setting of the indicator pointer is secured by the zero adjusting screw on the bottom of the case. This screw should be adjusted and then locked. If the gage is dismounted, the zero adjusting screw should be released and, to avoid damage while handling, the pointer arm should be secured by a clip accessible through a handhole in the top of the case. This clip should be disconnected and the zero adjustment carefully reset when placing the gage in service.

5A8. Air flow through individual cells. The flow of air through the cells of each battery compartment is equalized by adjusting regulators. These are installed as an internal part of each filling vent cylinder. (See Figure 5-7.) Proper adjustment of these regulators has been determined and set at a navy yard and must not be altered by ship's personnel.

NOTE. Do not permit the soft rubber nipples to become

voltage drop in the end-of-row connectors.

Separate leads are brought from the fused connection boxes to special connection boxes. One of these boxes is mounted on the forward bulkhead of the forward battery compartment and the other is mounted on the forward bulkhead of the after battery compartment. In Portsmouth-built vessels, the individual leads are brought up through the deck to the voltmeter panel without going through a special connection box.

Four 37-conductor cables connect each special connection box to its individual cell voltmeter station. Terminal tubes are used where these conductors enter the special connection box and the individual cell voltmeter switch box.

Each jack is identified by the number of the cell connected to it. The cell number is engraved on the phenolic panel, just below each jack.

The voltmeters are mounted just above the switch box.

The individual cell voltmeter panels are provided with enclosing

twisted. A twisted or partially collapsed nipple will materially affect the ventilation to the cell.

5A9. Voltmeter. There is an individual cell voltmeter switch panel for each battery. The panel for the forward battery is on the bulkhead at the after end of the wardroom country, and the panel for the after battery is on the side of the galley and mess room.

Each panel is composed of 126 jacks mounted on a phenolic panel and a 0- to 3-volt voltmeter with a 2-ft cable with plug attached. In the latest installations an additional 0- to 300-volt voltmeter is also installed. The latter voltmeter has a switch that can throw it either across cells 1 to 63, or across cells 64 to 126. It may also be used for reading grounds on the battery. (See Sections 3C4 and 3C5.)

Fused voltmeter lead connection boxes are mounted on the inboard cell connector of each set of 4 intercell connectors. They are also mounted on the positive terminal of cell No. 1 and the negative terminal of cell No. 126.

A fused connection box is mounted at both ends of the intercell connectors at the point where they connect the end cells, at the end of the rows in order to eliminate reading the covers which become data desks when in the open position.

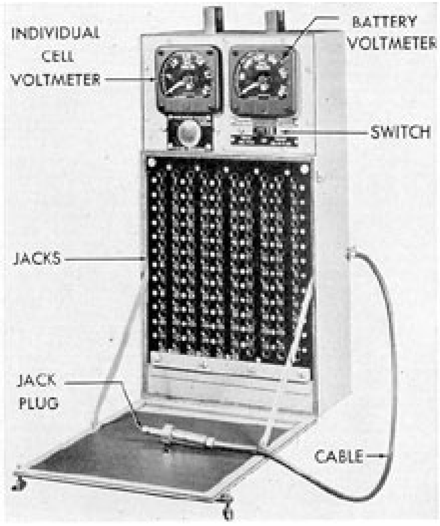


Figure 5-10. Individual cell voltmeter panel.

Version 1.10, 22 Oct 04

6
MISCELLANEOUS AUXILIARY EQUIPMENT

A. CIRCUIT BREAKERS

6A1. General. A circuit breaker is a device for opening an electrical circuit under load and it can also be used as a switch for closing the circuit. Circuit breakers may be either automatic or nonautomatic in operation. They are of two general types for direct current applications: carbon tipped and quenched arc types. The Navy designations for these types are ACB (automatic carbon break), and AQB (automatic quenched break) or NQB (nonautomatic quenched break).

The type ACB is represented on submarines by the I.T.E. type KN used on Electric Boat Company vessels and the General Electric type AL-2N used on Portsmouth vessels. The AQB types are represented by Westinghouse breakers and are used only on vessels of Portsmouth design previous to SS 381. On later Portsmouth vessels and on all Electric Boat Company vessels they are replaced with fused switches.

6A2. Type ACB breakers. The ACB breakers (Figure 6-1) used on submarines are live front, two pole, manually operated and trip free. They are enclosed for protection of personnel and are fitted with overload and short proportional to the current and thus, on a large current, the device trips faster. With currents greater than about 800 percent of rated current the solenoid pulls so hard that the whole dashpot is lifted against a strong spring. This trips the breaker in a short time and is known as instantaneous short circuit protection.

Reverse current protection is provided on the auxiliary generator breaker to prevent damage to the engine should the generator attempt to act as a motor when connected across the battery. This device consists of a small torque motor, that is, a motor that attempts to rotate but cannot turn a whole revolution. The field poles of the motor are energized by the line current in one pole of the breaker and the armature is energized by a coil connected across the two poles.

When the current is flowing in the normal direction the motor tends to rotate in one direction but is prevented from so doing by a stop. Should the current in the breaker reverse, the motor tends to rotate in the other direction. When the current reaches a certain value, the torque overcomes the pull of a calibrating spring and rotates until it hits a plunger which trips the breaker. The calibration

circuit protection and, in the case of the auxiliary generator breaker, with reverse current protection. They are equipped with a manual tripping handle which may be used as a hold-in device and, on the older less shockproof models, can be turned to lock the breaker in. Since this renders the breaker unable to open under overload, it should never be left in the locked position after the immediate danger of opening due to shock has passed. The overload protective device acts to trip the breaker after a time delay when the current exceeds a certain value, usually 125 percent full load. The time delay is obtained by an oil dashpot which consists of two accurately ground disks in a bath of oil. When the disks are close together, the oil film between them resists the efforts of the tripping solenoid to pull them apart. The time delay is inversely range of the reverse current trip is usually from 10 percent to 25 percent of the rated current. The action of the ACB breaker in rupturing the arc is simply a drawing out of the arc between the carbon tips as they separate. The linkage is designed so that the last points to separate are on the carbon tips, thus preventing burning of the current-carrying contacts which are silver tipped for low contact resistance.

6A3. Type AQB and NQB breakers. Type AQB and NQB circuit breakers used on submarines are dead front, two pole, manually operated, and on AQB breakers are trip free and fitted with short circuit protection. The arc in this breaker is interrupted in the following manner: As the contacts separate, the arc is drawn into a steel box insulated from the rest of the

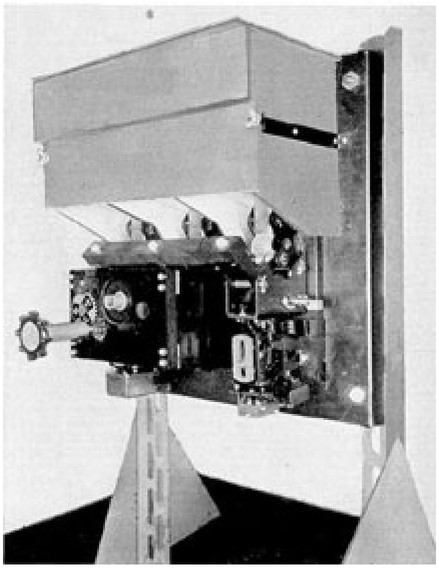


Figure 6-1. Type ACB circuit breaker.

breaker and slotted so that the are is separated into several pieces, thus greatly lengthening it and cooling it. Magnetic forces set up between the arc and the steel box cause the arc to move into the box.

The short circuit feature provided on AQB breakers consists of a short circuit trip element that is usually calibrated at the factory and is not easy to adjust. The best practice is to replace the element with a new one having the desired tripping characteristics. When tripped, the handle of the AQB breaker returns to a position

between OFF and ON. In order to reset it, the handle must be pushed toward OFF first and then to ON. NQB circuit breakers are entirely manual in operation and open only when the handle is turned to OFF. They have the same arc-interrupting features as the AQB breakers.

All AQB breakers are provided with a manual means of holding them in against overload and they can be locked closed against overload or shock. The locking devices should never be engaged except when absolutely necessary to prevent opening due to shock.

Figure 6-2. Type AQB circuit breaker, cover removed.

Figure 6-3. LIGHTING CIRCUIT LAYOUT DIMMER CONTROL ON 313 CLASS SUBMARINE.

Figure 6-4. EMERGENCY LIGHTING CIRCUIT LAYOUT ON 313 CLASS SUBMARINE.

B. FUSES AND FUSED SWITCHES

6B1. Fuses. Like circuit breakers, fuses are used to provide protection from short circuits. However, once the fuses have opened the circuit because of a distribution panels. The type used on submarines consists of metal boxes having fuses with knife blade connectors attached to a sliding piece inside the cover.

short circuit, they cannot be closed and must be replaced. Fuses depend for their action on the melting of a current-carrying strip of metal by the heat generated by the current in the strip itself. Fuses are generally selected so that they will interrupt the circuit when about 200 percent of the rated current passes through them. All fuses have a time delay action which is inversely proportional to the current. This is caused by the heat capacity of the fuse and surrounding parts. Care should be taken when installing fuses to see that good contact is made in the clips as a high-resistance connection will, generate heat and cause the fuse to blow at a low current.

6B2. Fused switches. Fused switches are used for disconnecting and connecting various loads on the auxiliary power system and to provide short circuit protection to the cables and

When the cover is closed normally, the fuse and attached blades may make a connection across the split type posts in the box; but pressing to one side before closing the cover causes the blades to make no contact and they are thus locked in the electrically open position. Fuses should never be replaced with fuses of greater capacity than that shown on the circuit diagram or marked on the label plate at the fuse holder or on the switch box.

Fuse retainers are installed on all fuses that can be jarred out of their holders by shock. These may be insulating blocks held over a line of fuses by thumbscrews or attached to the inside of the cover of the box; or they may be small clips of spring steel which increase the tension of the fuse holder prongs. Fuse retainers should always be replaced if they are removed for any purpose.

C. LIGHTING SYSTEM

6C1. Description. The lighting system includes the ship's service lighting system and the port and starboard emergency lighting systems. Each of the systems is a separate distribution system.

Power for the ship's service lighting system on late type submarines is obtained from the batteries through 2 lighting feeder voltage regulators (see Section 6D1) and a lighting distribution switchboard. On earlier ships, power for this system was supplied by lighting distribution to lighting fixtures and low-current outlets is through standard lighting distribution boxes with switches and fuses for each outgoing circuit.

The starboard emergency lighting system is powered directly through 2 cutout switches connected to the positive and negative end cell terminal connectors of the forward battery. These switches are connected to 13 lighting units, a circuit to the auxiliary gyro, and to the forward and after marker buoy circuits. A

motor generator sets (see Section 4C1).

On ships that take the lighting power directly from the batteries, a battery selector switch has been incorporated in the lighting distribution switchboard. This switch permits selection of either the battery or the shore connection as the source of power.

The feeders from the lighting distribution switchboard run the length of the ship on both sides and serve all regular lighting circuits through fused feeder distribution boxes. Final branch junction box provides a connection to the gyrocompass control panel for the alarm system.

The port emergency lighting system is directly powered through cutout switches connected to the positive and negative end cell terminal connectors of the after battery. The arrangement of this system is similar to that of the starboard emergency system except for the location of the circuits and the fact that there is no gyrocompass alarm connection.

Each lighting unit consists of two 115-volt lights, a protective resistor, and a snap switch, all connected in series as they always operate directly on full battery voltage.

6C2. Searchlight. The 12-inch incandescent signal searchlight requires a 120-volt d.c. supply. It is not considered a part of the lighting system because the supply is taken from a fused, double pole, single throw switch on the I.C. switchboard and led to a pressure-proof receptacle and snap switch on the bridge.

6C3. Maintenance. Pressure-proof type searchlights that are left in place permanently must be kept thoroughly clean and lubricated. The pressure-proof feature consists of a free flooding structure that drains rapidly after the submarine surfaces. Power should not be applied to the lamp until it has been out of the water approximately 2 minutes. Special care must be taken to keep all electrical connections clean, the moving parts lubricated and the aluminum surfaces painted to prevent corrosion.

CAUTION. Submerging with the light on or shortly after it has been used will break the searchlight bulb due to thermal shock. Diving with the light on or turning it on while submerged will blow the fuses.

D. LIGHTING FEEDER VOLTAGE REGULATORS

6D1. Description. Lighting feeder voltage regulators are used on some ships instead of rotates in one direction or the other in response to the voltage sensitive element.

motor generator sets, for the purpose of maintaining the lighting system voltage at 120 volts or below. Two units are used, one for the starboard and one for the port lighting circuits.

These regulators are basically rheostats in which a contact arm is moved, either manually or by a motor, across a circular rheostat contact face plate. Resistor tubes dissipate the excess voltage in the form of heat. When the battery voltage is high as, for example, during charging, the supply to each of the lighting voltage regulators which is obtained from one half of the batteries may be as high as 175 volts. The rheostat is then adjusted to absorb the difference between this supply voltage and the desired 120-volt load-voltage. The rheostat resistance is tapped so that it produces a voltage drop of not more than 2 1/2 volts per step at any current between 100 amperes and 12.5 amperes. The rheostat is designed to dissipate 5500 watts at the maximum condition of a 55-volt drop at 100 amperes. This rheostat will carry between 12.5 amperes and 100 amperes through a drop of 0 to 55 volts.

The assembly is actuated through a voltage regulator element, known as an HIR regulator element, and RAISE and LOWER relays. The element is a voltage-measuring device that balances the pull of its coils against the pull of a coil spring. The RAISE and LOWER relays serve to connect the rheostat motor so that it

Essentially, the regulator element has 2 parts, one moving and the other stationary. The moving armature carries a moving arm and is supported by 2 flat hinge springs. The stationary part consists of 2 stationary contacts with support members and magnetic circuit parts. One coil is mounted on each core. Each of these coils is rated at 27.5 milliamperes and has a resistance of 1950 ohms.

The coil spring is fastened between the moving arm and the stationary member by a lever which can be adjusted to obtain proper spring tension. The lower end of the moving arm carries 2 counterweights which statically balance the moving arm in a vertical position. The upper end of the moving arm carries a double face, moving contact between a pair of stationary contacts of the relays. These stationary contacts are the R (raise) and L (lower) contacts and can be adjusted to fix the operating position and travel of the moving armature in relation to the pole pieces.

The RAISE and LOWER relays consist of two parts, one stationary, the other moving. The stationary part consists of a base, core, coil, the stationary main contact, blowout coil, and the arc chute. The moving part carries the main moving contact at its upper end and a counterweight at its lower end for static balance.

The complete assembly is drip-proof in construction and louvers are provided for the escape of hot air. The maximum permissible temperature rise on the rheostat resistor tubes is 375 degree C.

CAUTION. Although the temperature may not reach the maximum of 375 degree C, care must be taken in handling or working around the equipment.

6D2. Manual operation. The correct procedure for manual operation of the regulators is as follows: Turn the control switch to the MANUAL position. Pull the rheostat handwheel to disengage the rheostat from the motor speed reduction gears. The voltage of the load is dependent upon the position of the rheostat arm. Turning the rheostat handwheel in a clockwise direction cuts out, or decreases, rheostat resistance and raises the load voltage. Turning the rheostat handwheel in a counterclockwise direction cuts in, or increases, rheostat resistance and lowers the load voltage.

6D3. Automatic operation. The following precaution must be observed before turning the control switch to the automatic (AUTO) position. Always adjust the rheostat position manually to give 120 volts on the lamp load. This is the value of voltage that the regulator element has been adjusted to maintain.

After manual adjustment to 120 volts, turn the control switch to the AUTO position. The moving contact of the regulator element will be centered or floating between the front and back stationary contacts. Both the RAISE and LOWER contacts will be open.

When the load voltage rises, either by load change or by increase of the charging generator voltage, the element closes its lower contact. This energizes the DECREASE relay, which

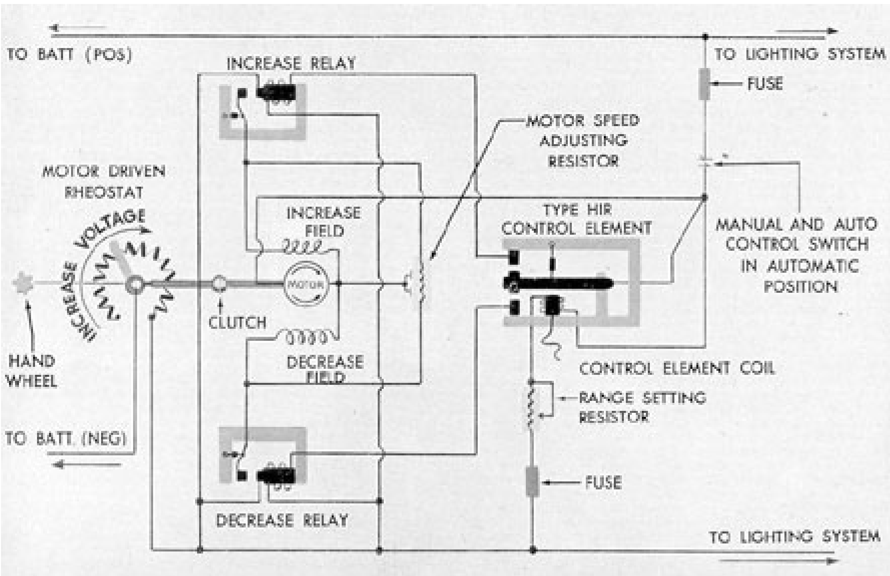


Figure 6.5. Schematic diagram of lighting feeder voltage regulator.

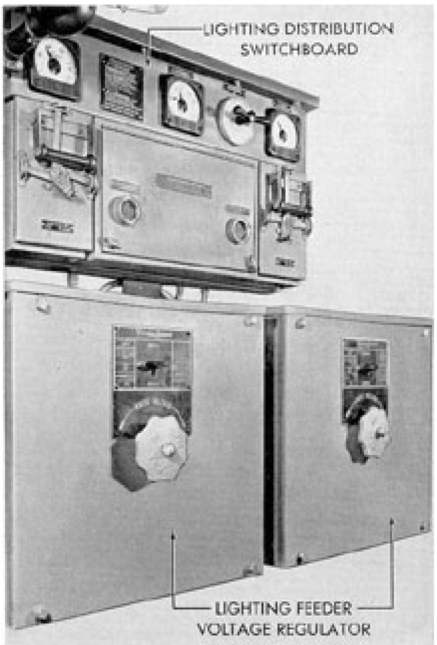


Figure 6-6. Lighting feeder voltage regulators and lighting distribution switchboard.

closes its contact in the motor field circuit. The motor drives the rheostat arm in a counterclockwise direction to cut in resistance and lower the load voltage. The action is continuous until the voltage is restored to 120 volts.

When the load voltage is lowered, the element closes its contact. Provided the load voltage has not been lowered to a value less than 50 volts, the increase relay closes its contact in the motor field circuit. The motor drives the rheostat arm in a clockwise direction to cut out resistance and raise the load voltage. The action is continuous until the voltage is restored to 120 volts.

NOTE. Large increases in load (over 50 amperes) should not be thrown on when the control switch is set on AUTO as this may cause the load and control voltage to fall below 50 volts, in

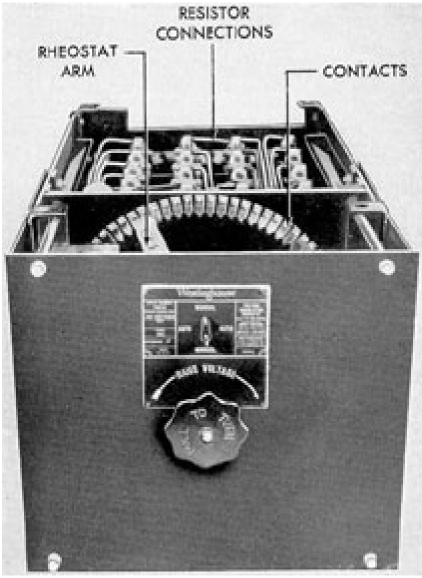


Figure 6-7. Lighting feeder voltage regulator, top removed.

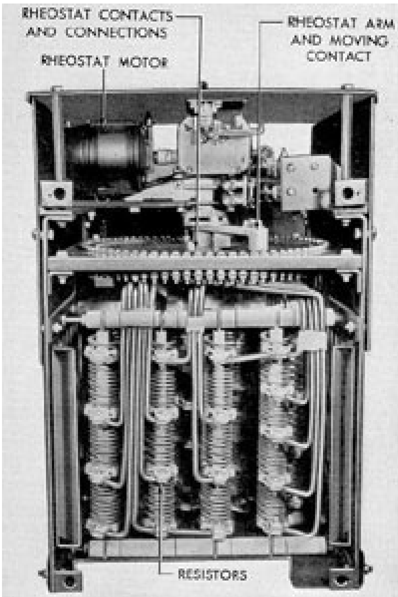


Figure 6-8. Top view of lighting feeder voltage regulator.

which case the INCREASE and DECREASE relays and rheostat driving motor will

fail to operate. In general, when set for automatic control, load steps should not exceed 50 amperes. Under manual control, precautions as to amount of load increase are not necessary, because the operator can take care of any load change within the rating of the rheostat. In view of the fact that overvoltage greatly reduces incandescent lamp life, when using manual control, an operating procedure should be established that will prevent large amounts of overvoltage.

6D4. General maintenance. The equipment requires only reasonable care to keep the contacts and the control element free of dust or dirt. The element contacts may be cleaned and polished without removing the contacts. A clean dry cloth should be used; emery cloth or other abrasives should never be used.

Moving parts should be checked periodically for free operation and to see that all moving contacts are in proper alignment with their stationary contacts. Main and auxiliary contacts should close at approximately the same time. The air gap between the moving and stationary main contact should be approximately 1/8-inch. A screw on the bottom of the moving arm is provided for adjustment of the air gap.

Lubrication of the rheostat motor should be checked periodically. The motor is equipped with 2 oil filler pipes, each of which has a screw head plug to permit refilling.

E. HEATING

6E1. Lubricating oil heaters. Four heater immersion units, each rated at 220 volts and 500 watts, are installed in each of the 2 lube oil heater assemblies. Each heater immersion unit consists of 3 blades separately enclosed in a steel sheath. The ends of the sheaths are brazed to the terminal housing of the immersion unit which is threaded for insertion into the heater housing pipe assembly. excessive sustained temperature and provided with an indicator showing that the cutout has tripped. The reset can be operated only after the machine has cooled to a safe operating temperature.

The 2-kw heater is rated 250 volts, at 8 amperes, and is similar in construction to the 4-kw heater except that each heater section is rated 500 watts, instead of 1000 watts.

In operation, the oil circulates through the heater housing pipes and, in its course, passes over each of the heater immersion units. The temperature necessary to bring the oil to its proper viscosity is controlled by cutting in or cutting out the required number of heaters, each of which is provided with an ON-OFF switch.

CAUTION. The immersion units must not be turned on unless oil is flowing. The units will burn out quickly if current is applied while they are not submerged in oil.

6E2. Air heaters. Portable 2-kw and 4-kw blower type heaters are installed on each vessel. The heaters are equipped with a switch providing 2 heating points. The switch positions are marked OFF, LOW, and HIGH. A self-contained fan is provided and is connected when the switch is turned to one of the heat positions. The 4-kw heater is rated 250 volts, at 16 amperes, and has 4 insulated heater sections cast in a circular fin type grid. Each pair of sections is protected by a thermal cutout, actuated by

Air heaters are fitted with protective devices to allow operation at 345 volts. However, during a long battery change at high voltage they may be turned to OFF or LOW as a further safety precaution.

6E3. Hot water heaters. The hot water tanks are of 20-gallon and 25-gallon capacity, heated by rod type heating units that are thermostatically controlled by magnetic contactors. The 20-gallon tank is equipped with 2 heating units, and the 25-gallon tank, with 3 heating units. Each heating unit is rated at 4 kw at 275 volts, and will operate satisfactorily over a range of 200 to 345 volts. Two watertight terminal boxes are provided. The lower box affords access to and contains the connections of the heating units. The upper box affords access to and contains the thermostat. The thermostat is adjustable for any temperature range from 120 degrees F to 180 degrees F and operates on a change of +- 5 degree F.

When properly vented, the tank is

completely filled with water at all times. The water temperature is maintained in accordance with the setting of the thermostat that controls the coil circuits of magnetic line contactors in the controller. When the water temperature falls below the thermostat setting, the thermostat closes the coil circuit, causing the contactors to close

6E5. Galley range. The galley range consists essentially of a cooking surface and an oven. These units and their heating elements are supported in the reinforced range body. The cooking surface and the oven are each independently controlled by two 3-heat reversible indicating switches and each switch is protected by a double pole cutout.

and connect the heating units to the line. When the water in the tank reaches the desired temperature, the thermostat opens, opening the contactors and disconnecting the heating units from the line. Operation of each tank is controlled by an ON and OFF tumbler switch located on the magnetic line contactor panel.

6E4. Coffee urns. The urn consists of 2 cylinder-type containers, one mounted within the other. An air chamber between the containers prevents cooling of the coffee in the inner container when fresh water is run into the water tank.

The water tank is heated by 2 immersion units, both controlled by a single 3-heat-indicating, reversible control switch mounted in a switch box located in front of the unit. The immersion heating units are installed through the back of the urn body in the lower part of the water compartment. The unit heads, terminals, and leads are housed under a removable cover plate.

Each of the heating units has a rating of 1000 watts at 250 volts. The input of the urn, at rated voltage, is 2000 watts on HIGH, 1000 watts on MEDIUM and 500 watts on LOW. The urn capacity is 2 gallons of coffee and 4 gallons of water.

CAUTION. The heating units must not be turned on unless the urn is filled with water and must always be shut off or turned to LOW during a long battery charge at high voltage, in order

The cooking surface heating elements consist of a nickel chromium resistor imbedded in an insulating material within a seamless steel sheath which is cast as a unit into the cooking surface casting. The cooking surface has an area of 19 inches by 18 inches and is rated at approximately 4000 watts on HIGH, 2000 watts on MEDIUM, and 1000 watts on LOW. The terminals are sealed to prevent air, moisture, or grease from entering the heating coils.

The insulated oven compartment is approximately 17 inches wide, 18 inches deep, and 14 inches high. The oven is provided with an adjustable automatic temperature control and indicator with a range between 200 degrees and 550 degrees F. Two heating elements are used; one is located at the bottom, the other at the top of the oven.

The oven heating elements are of the same construction as the cooking surface elements except that they are enclosed in nickel chromium tubing and are supported in a steel frame. Each heating unit is rated at approximately 1500 watts on HIGH, 750 watts on MEDIUM, and 375 watts on LOW at 250 volts.

All heating elements are capable of operating continuously at any voltage up to 345 volts without detrimental oxidation.

The range is constructed for heavy duty service and should require little electrical maintenance. Spare heating elements, switches and temperature control units are carried on board for replacements

to protect the units from the
damaging high voltage.

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Figure 6-3. LIGHTING CIRCUIT LAYOUT DIMMER CONTROL ON 313 CLASS SUBMARINE.

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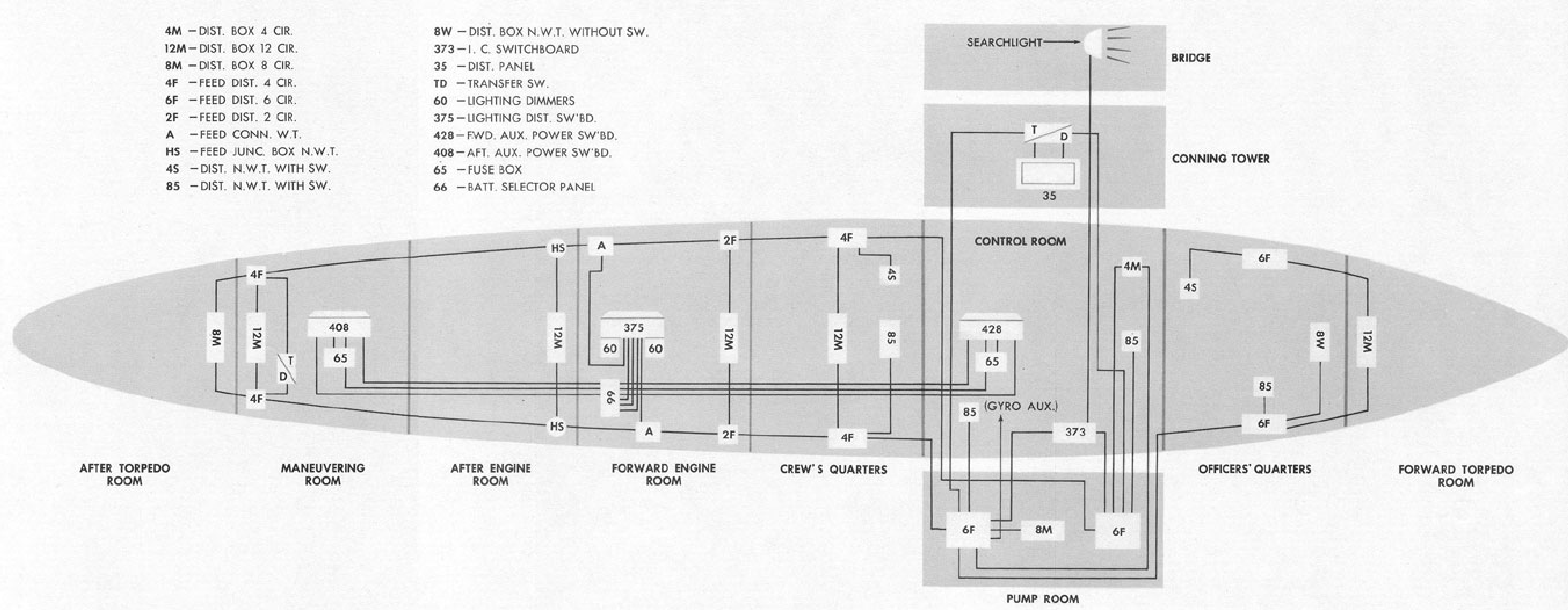

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Figure 6-4. EMERGENCY LIGHTING CIRCUIT LAYOUT ON 313 CLASS SUBMARINE.

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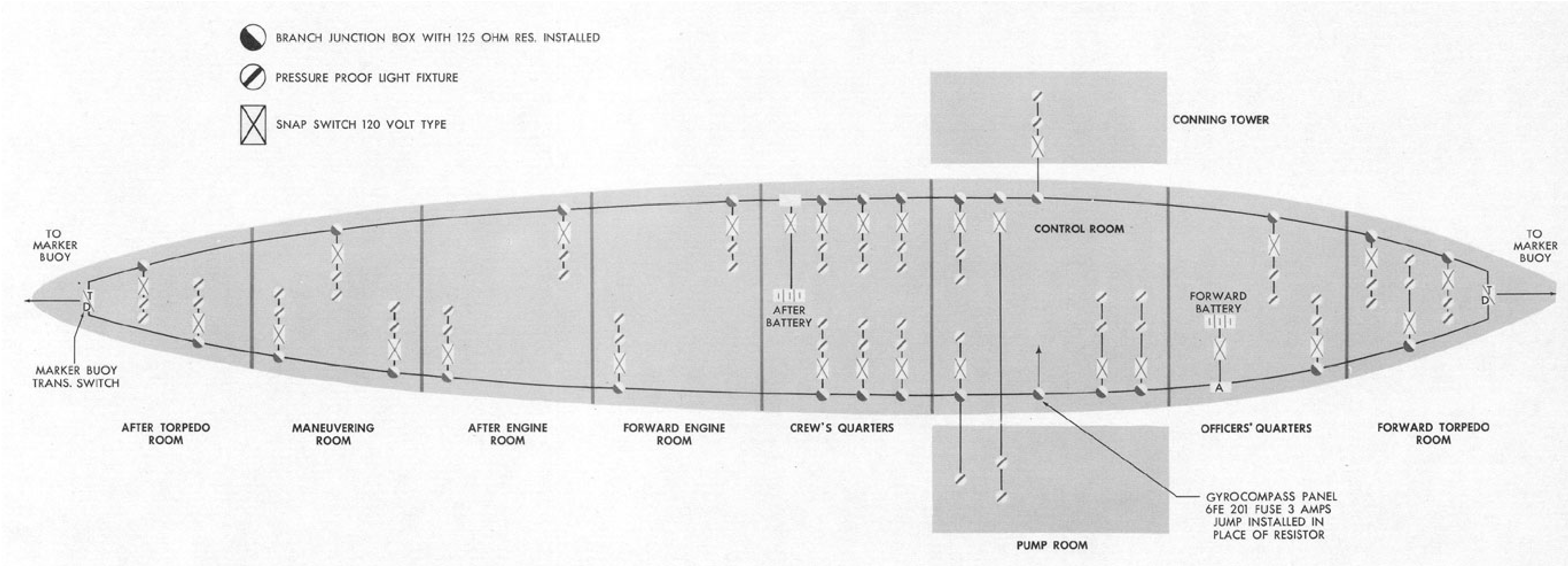

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7
MAINTENANCE OF ELECTRICAL EQUIPMENT and MEASUREMENT OF INSULATION RESISTANCE

A. MAIN MOTORS AND GENERATORS

7A1. Inspection and cleaning. Frequent inspection and cleaning are necessary to insure trouble-free operation and long life of motors and generators. Machines should be examined for cleanliness, proper lubrication, tightness of connections, and freedom from moisture before every start.

Inspect the commutator frequently for uniform, hard surface gloss. Check for serious roughness and dirtiness of the slots between segments. Examine the brushes for wear and freedom in the brush holders. Check the brush holder spring tensions and see that pigtail connections are tight. Inspect the windings for presence of dirt and oil and clean them if necessary. Accumulations of brush dust must be removed. Check the bearings for adequate lubrication, signs of wear, and condition of the journal surface; scoring is likely to be an evidence of the presence of foreign particles in the lubricating oil. Joints in connections and at terminals must be inspected to make certain they are tight. Careful inspection must be made to insure that there is no oil leakage electrical machinery is operated under adverse conditions, due to the continual moisture, and the many sources from which lubricating oil may find its way inside the machine casing.

Loose dust or foreign particles located in accessible parts of the machine may be removed by wiping with a clean dry cloth. Cheesecloth is recommended for this purpose. Do not use a cloth that deposits lint.

Compressed air is effective in removing loose foreign matter from inaccessible locations. Its use, however, is not recommended unless the machine can be opened sufficiently to permit air and dirt to escape. There is always danger of blowing abrasive particles into insulation or beneath insulating tapes.

The use of suction is preferable since there is less possibility of damaging insulation. A flexible tube attached to the suction side of a portable blower makes a suitable vacuum cleaner for this purpose. Grit, iron dust, and copper particles should be removed by this method only, whenever possible.

into the machines. Check to see that the joints on all covers and shields are tightly sealed. Inspect the equipment in operation for sparking, vibration, and temperature. Cleanliness is one of the most important factors in proper maintenance of motors and generators. Keep both the interior and exterior of the machines free from water, salt, lint, dust, dirt, and particularly, oil.

Most of the casualties to main motors and generators of submarines may be attributed to lubricating oil or other foreign matter reaching the commutator, armature, or field coils. This gradually breaks down the insulation and finally results in burned-out coils or armatures. The penetrating and damaging effect of oil in electrical apparatus is universally known and must always be carefully guarded against. This is especially true in the submarine service where

If the accumulation of dirt on insulation surfaces contains grease or oil, a solvent is usually necessary to remove it. An approved nontoxic and nonexplosive solvent must be used and then only sparingly. The solvent should be applied by moistening a lintless cloth with the fluid and lightly rubbing the surfaces to be cleaned. Excessive use of solvent may soften the insulation. After cleaning, the surfaces should be dried thoroughly to remove all traces of solvent.

CAUTION. Carbon tetrachloride is one of the best solvents for this purpose; but it must not be used in confined spaces and must never be taken to sea in a submarine due to its toxic properties. Crews of submarines have been poisoned by its fumes.

7A2. Definition of insulation resistance. When a constant potential is impressed across insulation, the current which flows is inversely proportional to the resistivity of the insulation. Depending upon the physical arrangement of the conductors and insulation, the paths followed by the current may become somewhat complicated. In general, however, the current flow is through the body of the insulation or over its surface, or through a combination of both. The resistance opposing this flow

1. A direct reading ohmmeter of the hand-driven generator type (megger).

2. The ground detector system (Sections 3A15, 3C4, and 3C5) for main propulsion motors and generators by converting the voltmeter readings into resistance values.

3. A voltmeter (high-resistance type) or milliammeter and a d.c. voltage supply.

4. A resistance bridge.

of current is defined as insulation resistance.

5. A direct indicating ohmmeter of the generator, battery, or electronic type.

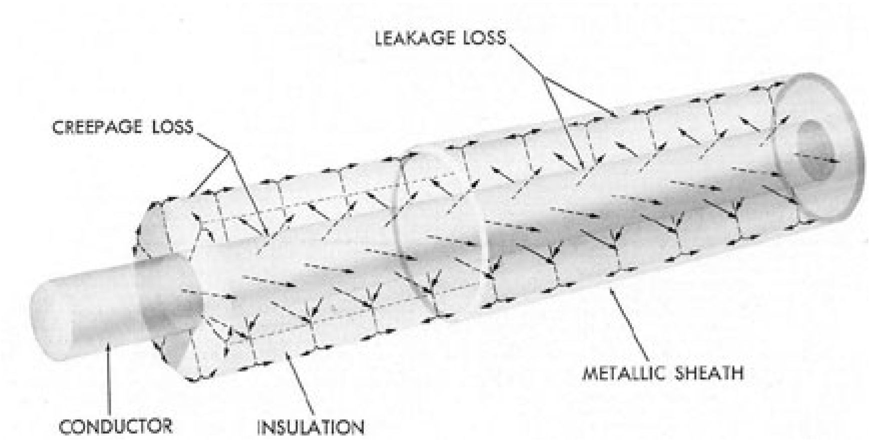


Figure 7-1. Leakage paths in cable construction.

Insulation resistance may be measured without damage to the insulation. A correct interpretation of such a measurement is usually the most convenient measure of the condition of the insulation. It can be used as a guide in determining when cleaning, drying, or overhaul is necessary, thereby preventing further development of conditions which might eventually lead to insulation failure in service. A properly interpreted reading may also eliminate needless shutdowns, overhauls, or renewals to improve insulation resistance that is entirely adequate.

7A3. Methods of measuring insulation resistance. Insulation resistance may be measured by various instruments such as:

In the second method, the circuits to be tested must be energized to cause a deflection. This method, therefore, provides a convenient means of testing for grounds and measuring insulation resistance with no interruption in service. Methods 1 and 2 are the most commonly used.

If a megger is used, the circuit must be deenergized while the instrument is used to take readings, and the hand-driven generator should be cranked as long as practicable to obtain a steady reading. Subsequent tests should be made in the same manner so that readings will be comparable.

If the portable voltmeter method is used,

care should always be exercised to restrict the applied voltage to a value commensurate with the condition of the insulation. It should also be noted that the

apparatus or circuit, the date, and the condition under which the reading was taken. Any change that may have taken place can

resistance of the voltmeter has a direct bearing on the accuracy of the results. A voltmeter having a sensitivity of 100 ohms per volt does not permit measurements in excess of 2 megohms with any degree of accuracy for an applied voltage of 500 volts. The maximum resistance that can be measured with voltmeters having a sensitivity higher than 100 ohms per volt increases in direct ratio to the sensitivity in ohms per volt.

The instruments used in insulation resistance testing should be well maintained and periodically checked to insure that the rated voltage is delivered and that the instrument is in calibration.

7A4. Records of insulation resistance measurements. Suitable forms, such as the Megger Test Record (Figure 7-2), are provided for keeping accurate records of measured values. When properly filled out, the forms give the thus be noted by comparison with previously recorded values on file.

7A5. Factors affecting resistance values. The principal factors that may influence values of insulation resistance measured in service are:

1. Connected cable and electrical apparatus. Other apparatus connected in the circuit may have an important bearing on observed values. For example, when measurements are taken on a generator connected to a switchboard, the value obtained includes not only the resistance of the generator circuits but also that of the bus work of the switchboard, all apparatus connected to the bus, and the generator cables. Since the insulation resistance of all this equipment is in parallel, the measured value may be quite low, but no conclusion as to the condition of the generator may be drawn from the value obtained. The reading indicates merely that the

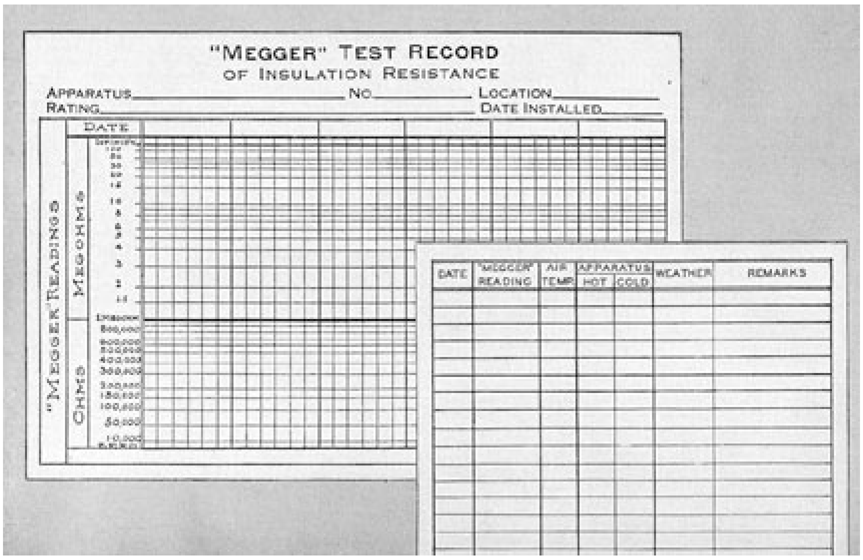


Figure 7-2. Megger test record card.

insulation resistance of the current through the conductors or

circuit, as a whole, is low.

For preliminary significant measurements, the machine should be isolated only to the extent of opening line switches, circuit breakers, and conductors. The insulation resistance measurement taken in this manner will still include the effect of connected cables and equipment that cannot be conveniently disconnected. For this reason, further isolation must be undertaken if precise readings of the apparatus in question are to be obtained. Armature windings, for example, may be further isolated by lifting all brushes off the commutator; shunt field circuits may be broken up by disconnecting the leads connecting successive poles; and cables may be isolated by completely disconnecting the cable at both ends. The degree of isolation must be progressive if it is to determine accurately the weak spots. As more isolation is undertaken, higher resistance values should be expected within the component part of the circuit involved, because of the reduction of possible parallel current paths to ground.

NOTE. Before proceeding with complete isolation, corrective measures, such as elimination of excessive moisture in the insulation, condensation on its surfaces, and removal of accumulated foreign matter, should be undertaken. Tests may then show sufficient improvement in the insulation resistance to eliminate the necessity of breaking the internal connection within the machine.

externally by heaters used to raise the temperature in the affected area. If, however, in addition to moisture, the insulation has deteriorated from exposure to oil, acid, or other harmful matter, the insulation resistance probably cannot be restored to its original value.

3. Temperature. The resistance of any insulating material varies with temperature. The resistance of copper and other common con ducting materials increases with temperature rise, the resistance of insulation decreases as the temperature rises. The presence of moisture in the insulation also greatly affects the values of insulation resistance at different temperatures. Temperature must always be taken into consideration when observed values of insulation resistance are being interpreted. When readings are taken at intervals, the values may be properly compared only when taken at approximately the same temperature or when due allowance is made for differences in temperature. Similarly, readings taken at room temperature must be compared only with previous, readings under the same conditions of humidity.

4. Cleanliness. The condition of the insulation influences the value of insulation resistance. Foreign matter such as dust, salt, carbon, or copper dust form conducting paths. The presence of oil or moisture acts as a binding agent and encourages the accumulation of such foreign matter, increasing the conductivity of the paths. The windings of rotating electrical machinery particularly collect such deposits in service. Other factors

2. Moisture. Moisture content has a significant effect on insulation resistance and must be taken into account. All insulating materials absorb moisture from the atmosphere, some more readily than others. For example, cotton, paper, and asbestos insulation materials absorb moisture more readily than does mica. Vacuum pressure impregnated insulation keeps out moisture more effectively than built-up or immersion impregnated insulation. Insulation that has cracked or is otherwise damaged usually is more susceptible to moisture absorption, other conditions being equal.

Normally the moisture may be driven off or evaporated by the application of heat. Heat may be applied internally by the passage of

remaining constant, the relative variations in insulation resistance over a period of time are an indication of the degree of cleanliness of the insulation. A winding that may be in good condition in all other respects may have a low insulation resistance caused solely by deposits of foreign matter. After a thorough cleaning, the value may increase to an acceptable amount.

5. Condition of insulation. Any insulating material deteriorates with age, due to the individual or combined effects of heat, moisture, vibration, mechanical injuries, oxidation, and chemical action from acid or alkali fumes, salt, air, oil, and so forth. The rate of deterioration

depends upon the conditions to which the insulation is exposed, such as location, type of service, atmosphere, and the amount of care. Although deterioration is inevitable, the life of the insulation may be lengthened appreciably by constant intelligent maintenance suited to the service conditions imposed.

6. Residual charges. Residual charges of static electricity, if present in a winding, affect insulation resistance measurements and should therefore be removed by grounding the conductors for a few minutes before measurements are made.

The types of bonding and coating varnishes and the drying processes used also have considerable influence. Duplicate machines constructed in the same shop may differ in their insulation resistance because of the variations that occur in their manufacture.

Before tests are made, detail drawings should be consulted to ascertain what type of insulation is under test.

8. Summary. Because of the various factors enumerated in the foregoing section, no rigid rule or formula has been established regarding acceptable values of insulation applicable to all types of

7. Construction. In the case of rotating electrical machinery, the dimensions, shape, number of turns, type of insulation, and process of manufacture influence the insulation resistance of the windings of machines. Windings in large or low-voltage machines will have inherently lower insulation resistances than those in small or high-voltage machines. Field windings will have inherently higher values than direct current armature windings due to the numerous creepage paths at the commutator connections.

machines. For main propulsion d.c. motors and d.c. generators, as well as for any motor rated at or above 50 hp, and generators rated at 35 kw or more, a table is supplied outlining the minimum acceptable insulation resistance of the various circuits. For smaller machines, the operating personnel must be guided by comparing measured values of insulation resistance with similar data previously recorded, noting also the particular conditions under which they were obtained.

APPARATUS	MOTORS AND GENERATORS IN SERVICE (SEE NOTE 1)		
DIRECT CURRENT PROPULSION MOTORS AND GENERATORS	BEFORE CLEANING DIRTY MACHINES IN VESSEL	AFTER CLEANING IN VESSEL	AFTER RECONDITIONING IN SHOP
ARMATURE CIRCUIT COMPLETE	$R_a = R \times 0.3$	$R_b = R \times 1.5$	
ARMATURE ALONE	$R_c = R \times 0.45$	$R_d = R \times 2.25$	$R_e = R \times 5$ (SEE NOTE 2)
ARMATURE CIRCUIT LESS ARMATURE	$R_f = R \times 0.45$	$R_g = R \times 2.25$	$R_h = R \times 5$ (SEE NOTE 2)
SHUNT FIELD CIRCUIT COMPLETE	$R_i = R \times 2$	$R_k = R \times 5$	$R_L A = R \times 10$

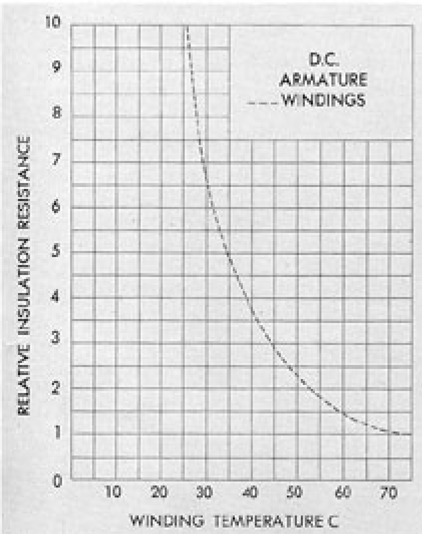
WHERE: $R = \dfrac{E}{\dfrac{KW}{100} + 1000}$

E = RATED VOLTAGE OF MOTOR OR GENERATOR
KW = KILOWATT RATING OF GENERATOR
KW = HORSEPOWER RATING OF MOTOR x 0.746
R, R_a, R_b, R_c, ETC. = INSULATION RESISTANCE IN MEGOHMS

NOTE 1: – WHERE MEASUREMENTS ARE MADE AT TEMPERATURES ABOVE 25°C (77°F) THE VALUES LISTED IN THE TABLE MUST BE CORRECTED BY USE OF CURVE GIVEN IN FIGURE 7-4

NOTE 2: APPLY HIGH POTENTIAL TEST ONLY AFTER RECONDITIONING IN SHOP WITH TEST VOLTAGE OF 2/3 (2E + 1000)

Figure 7-3. Minimum insulation resistance of dry direct current propulsion motors and generators based on readings of 25 degrees C or 77 degrees F.



insulation resistance, after cleaning, is equal to or greater than R_b, the machine should be placed back in service; if the measured value of insulation resistance is less than R_b, the several parts of the armature circuit should be disconnected and each part measured separately to determine if any one part of the circuit is causing the trouble. After the several parts are isolated from each other, if one particular part is

Figure 7-4. Effect of temperature on insulation resistance of insulated windings.

7A6. Explanation for use of table (Figure 7-3) for d.c. propulsion motors and generators. a. General. The values R_a, R_c, R_f, and R_j, indicate the minimum desirable insulation resistances under operating conditions for the circuits shown. When values less than these are obtained, action to further investigate the cause and remedy it, as indicated below, is necessary. It is recommended that whenever insulation resistance values less than R_a, R_f, R_j are obtained, the equipment concerned should be cleaned at the first available opportunity.

b. Armature circuit complete. Before any cleaning is attempted, measure insulation resistance of armature circuit complete, including armature, compensating fields, commutating fields, series fields, brush rigging, and connections to machine terminals. This resistance is measured by connecting the testing instrument between one armature terminal and ground. If the measured value is equal to or greater than R_a, but cleaning appears desirable, an attempt should be made to clean the machine in place without disassembly except for the removal of the access plates. If the measured value of found to be causing the trouble, that part should be treated individually. When the several parts of the armature circuit have been disconnected, and the low insulation resistance still cannot be attributed to any particular part of the circuit, the machine should be recleaned to insure that it has been properly done. If after a thorough check of the cleaning, the insulation resistance of the armature circuit complete is still less than R_b and the trouble cannot be isolated, the machine should be removed and reconditioned in a yard or base shop at the first opportunity.

If the measured value of insulation resistance for the armature circuit complete is less than R_a before cleaning, the several parts of the armature circuit should be disconnected from each other and each part should be treated as outlined below.

c. Armature alone. If the insulation resistance of the armature alone is equal to or less than R_c before cleaning, it should be cleaned in the vessel. If the insulation resistance of the armature alone when cleaned is equal to or greater than R_d, the armature is suitable for service.

If the insulation resistance of the armature alone when it has been cleaned, is less than R_d, the armature should be removed at the first available opportunity to a yard, base, or tender for reconditioning. After reconditioning, the insulation resistance should not be less than R_e. After such reconditioning has been completed the armature

alone should be given a shop high-potential test of 2/3 (2E + 1,000) volts, E being the operating voltage of the machine.

d. Armature circuit less armature. If, previous to cleaning, the insulation resistance of the armature circuit less armature is equal to or less than R_f, it should be cleaned in the vessel. If the insulation resistance of the armature

circuit less armature when cleaned is equal to or greater than R_g, that part of the equipment is suitable for service. If, after cleaning, the insulation resistance of the armature circuit less armature is less than R_g, the various parts of the circuit should be isolated to determine if one part is causing the trouble. In some cases, the low insulation resistance may be caused by dirt, oil, or defective insulation at one spot such as in one pole, or at one brush rigging stud, and so forth. If the low insulation resistance cannot be traced to some particular part or spot, all parts of the armature circuit less armature should be removed at the first opportunity for reconditioning. After reconditioning, the insulation resistance of the armature circuit less armature should not be less than R_h. The reconditioning should be followed by a shop high-potential test of 2/3 (2E + 1,000) volts.

e. Shunt fields. If the insulation resistance of the shunt field circuit complete prior to cleaning

Therefore the applicable minimum values at 25 degree C are:

R_a .41 X .3 = 0.123 megohms
R_b .41 X 1.5 = 0.615 megohms
R_c .41 X .45 = 0.185 megohms
R_d .41 X 2.25 = 0.923 megohms
R_e .41 X 5.0 = 2.05 megohms
R_f .41 X .45 = 0.185 megohms
R_g .41 X 2.25 = 0.923 megohms
R_h .41 X 5.0 = 2.05 megohms
R_i .41 X 2.0 = 0.82 megohms
R_k .41 X 5.0 = 2.05 megohms
R_l .41 X 10.0 = 4.1 megohms

1. Armature circuit complete. Assume that the following conditions prevail:

a) Measured value of the insulation resistance of the armature circuit complete is 0.160 megohms. This value is greater than R_a (0.123 megohms); and the armature circuit complete should be cleaned in place.

b) After cleaning, the measured value of the insulation resistance of the armature circuit complete

is equal to or less than R_i, the shunt fields and connections should be cleaned in place. If the insulation resistance of the shunt field circuit complete after cleaning is equal to or greater than R_k, that part of the equipment is suitable for service.

If the insulation resistance of the cleaned shunt field circuit complete is less than R_k, each shunt field coil should be disconnected and measured separately to determine if one coil is causing the trouble. If the cause of the low insulation resistance can be traced to one pole, that pole should be removed for reconditioning or the coil should be replaced with a spare. If the cause of the low insulation resistance cannot be traced to one coil, all coils should be removed for a yard, base, or tender reconditioning. After reconditioning, the insulation resistance of the shunt field circuit complete should not be less than R_l.

f. Example of above discussion. Assume that a submarine requires the cleaning or overhaul of a propulsion generator. The rating of the generator is 415 volts, 1100 kw. The temperature of the generator is 25 degrees C, or 77 degrees F, and the machine is dry.

$R = 415 / ((1100/100) + 1000) = 0.410$ megohms

was 0.450 megohms which is less than the minimum R_b (0.615 megohms).

c) The armature alone was disconnected from the armature circuit complete and was measured alone. A value of 1.2 megohms, which is greater than R_d (0.923 megohms), was obtained, indicating that the armature was satisfactory for service.

d) The measured value of insulation resistance of the armature circuit less armature was found to be 0.75 megohms which is less than R_g (0.923 megohms), indicating that the armature circuit less armature needed additional cleaning or that there was some isolated low-resistance path. The compensating windings, the commutating windings, and the brush rigging were disconnected from each other and measured separately. The compensating winding measured 4.0 megohms, the commutating winding measured 1.0 megohms, and the brush rigging measured 4.0 megohms, indicating that a low-resistance path to ground was somewhere in the commutating pole winding. Each commutating pole winding was disconnected and measured separately and it was found that one commutating field pole had lower insulation

resistance than any of the other commutating field poles. Upon further investigation, it was

bruises due to retainers. Insulation will occasionally require a coating of insulation varnish. Only high-

found that one of the less accessible spots of the pole had not been adequately cleaned. After cleaning, the insulation resistance of the pole in question was measured and found to be equal to all of the other poles. All parts of the armature circuit less armature were then reconnected and the insulation resistance measured. A value of 1.2 megohms which is greater than R_g (0.923 megohms), was obtained, indicating that these parts were satisfactory for service. The armature was then connected in the circuit and the armature circuit complete gave a measured insulation resistance value of 0.750 megohms which is greater than R_b (0.615 megohms), and the armature circuit complete was ready for service.

2. Shunt field circuit. The measured value of insulation resistance of the shunt field circuit complete before cleaning was 0.10 megohms which is less than the minimum value of R_i (0.82 megohms). Each shunt field coil was disconnected and tested separately; one coil was found to have much lower insulation resistance than any of the other coils. The defective coil was removed and it was found that the insulation between the coil and the metal pole piece had been damaged, allowing a low-resistance path to ground. The damaged insulation was renewed and all the shunt field coils were cleaned and reconnected. The insulation resistance then measured 3.50 megohms, which indicated that grade air-drying insulating varnish must be used. Apply two thin coats only, suitably thinned in accordance with the directions of the varnish manufacturer. Care should be taken to avoid clogging air vents, and any excess varnish should be removed before it sets. All insulating surfaces such as mica, cone extensions, brush insulation, and so forth, should also be coated with varnish. It is essential that varnish be applied only on clean, dry surfaces after all necessary repairs and cleaning have been effected. Varnish may be applied either by spraying or with a brush. It should be noted that the application of varnish will not permanently increase the insulation resistance or dielectric strength of the insulating material and accordingly cannot be used as a substitute for repairing or replacing defective insulation.

7A8. Condensation. To prevent condensation during extended shutdown periods, the temperature within the machine must be kept higher than the outside temperature. Condensation can be prevented, or eliminated, if found, by circulating heat through the machine. A convenient means of heating the machines is to leave the shunt fields energized at a low current. Do not exceed the maximum field current allowed in the manufacturer's instruction book for nonrotating machines.

CAUTION. Always secure the circulating water to the main motor or generator coolers when the machines are secured. If this precaution is not observed, condensation may take place on the cooler core.

the shunt field circuit complete was ready for service.

7A7. Repairing defective insulation. Windings should be cleaned and dried before any repairs are attempted. When a defect is located, either a permanent or a temporary repair should be made as circumstances will permit. All connections should be maintained tightly and suitably taped where necessary. Wedges should be maintained tightly in their slots and any loose space should be filled with slot fillers. Binding bands and bolted and soldered connections should be checked because the effect of magnetic stresses, vibration, and cycles of temperature variation constantly tend to loosen bands and connections. Field coils should be checked for tightness on field poles and for evidences of

Moisture absorbed by insulation or condensed on its surfaces may result in short circuits or grounds. The dielectric strength of the insulation is lowered temporarily while moisture is present and may be permanently lowered if deterioration occurs. For these reasons, moisture should not be allowed to accumulate, and a machine should not be placed in service without first making certain that the insulation is dry.

Insulation may be dried out with a hot air heater, allowing the hot air to enter through a port at the bottom of the machine and the

moisture-laden air to escape through a port at the top. If insulation resistance is not too low, reduced current may be passed through the shunt field coils. The voltage and current should be gradually raised as the machine dries. Constant circulation of air is important. If an outside source of air is used, make certain that the air is clean and free of moisture. It is a good practice to energize with a low current daily all fields on machines that are not in use in order to dry them and keep them above room temperature.

other direction, perpendicular to the commutator bar, between the brush and the holder should be 0.005 in. to 0.014 in. Check the brushes frequently to see that they are not sticking in the holders, that leads are firmly attached to the brushes and the holders, and that the pigtails are not rubbing on any part of the machine. Worn-out brushes must be replaced before they reach the end of their travel and break contact with the commutator.

The insulation resistance should be measured before, and at intervals during, the drying process. The interval between readings may vary with the rate of drying and the convenience in making the measurements. The insulating resistance decreases rapidly at the early stages of drying; but as the temperature becomes constant and evaporation progresses, the insulation resistance begins to increase, rapidly at first, then at a slower rate. When the readings reach a constant value and are sufficiently high, the drying-out process is complete and may be discontinued. Complete drying may take 24 hours or longer, depending on the heat and air circulation.

7A9. Brushes and rigging. a. General. The brush rigging is doweled in its proper position by the manufacturer. A machine must never be operated unless these dowels are tight and the rigging properly positioned. In the event of a change of position, old marks must be obliterated and new reference positions definitely determined and marked.

Brush brackets should be kept in their original positions so that they are square with the commutator segments and so that the distances between the brushes around the commutator are equal.

Brush holders are removable and fit in grooves to assure proper alignment. Brushes should not be loose in the holders, nor should they be so tight that they do not move freely. There should

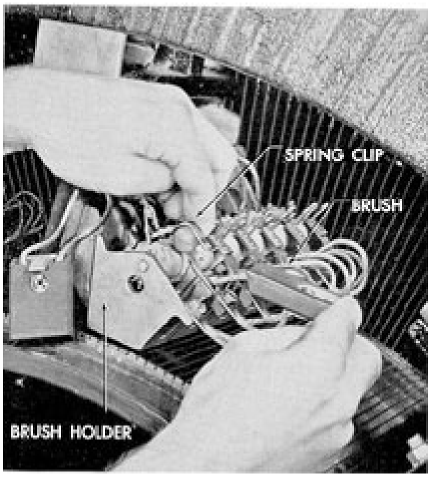


Figure 7-5. Brush removal.

If sparking of the brushes is encountered, check for the following possible causes:

1. overload

2. incorrect positioning of the brush rigging

3. worn-out, burned, or incorrectly fitted brushes

4. brush holder brackets out of alignment

5. rough, dirty, or insufficiently undercut commutator

6. open circuit or loose connection in the armature

7. loose connection between pigtail and brush or pigtail and holder

be a clearance of 0.005 in. to 0.025 in., measured in line with the shaft, between the brush and the holder. The clearance in the

NOTE. Brushes having loose pigtail connections, while they may not spark themselves, will often cause other brushes to spark because the defective brushes do not take their share of the load.

b. Procedure for reassembling brush holders. Whenever it becomes necessary to disturb the original adjustment of the brush holders, the following procedure should be followed in reassembly:

1. Set up the brackets with the brush holders in place and wrap a long strip of paper around the whole circumference of the commutator. Mark the lapping points of this paper; lay it on a flat surface, and divide the space between the marks into as many equal spaces as there are brush arms. Mark each division point, wrap the paper around the commutator, and adjust the brush brackets until the toes of the brushes of the different brackets just touch the marks. All brush holders should be the same distance from the commutator - not less than 0.080 in. or over 0.100 in. The toes of all brushes on one bracket must be in line with the edge of one commutator segment. If a bracket is out of line, loosen the bolts and adjust to the proper alignment by shimming or filing under the bracket head.

the holders should be sanded separately from those on the other side, moving the sandpaper always toward the center of the holder with the drag on the brush also toward the center. Continue the sanding operation until the brushes make firm, even, and complete contact with the commutator face.

c. Spring tension. Frequent adjustment of the spring tension is not necessary, but it is advisable to check the springs and possibly the tension when the brushes are worn down approximately halfway. The brush pressure should be about 2.5 psi of contact area between the brush and commutator. A small spring balance may be used for checking the brush spring pressure as shown in Figure 7-6.

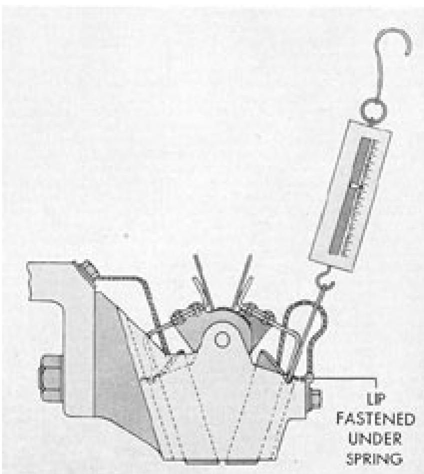


Figure 7-6. Method of measuring brush spring pressure.

d. Brush yoke setting. Shifting of the brushes around the commutator effects both the

Occasionally slight filing to increase the clearance in the bolt hole may be necessary. Correct staggering of the brushes has been provided for by suitable drilling of the brush holder brackets.

2. After the brushes have been properly spaced, they must be sanded to fit the curvature of the commutator. Fine sandpaper may be used. Do not use emery or carborundum. Remove the carbon dust with a cloth as it will cause serious trouble if allowed to collect on the winding. To fit the brushes with sandpaper, lift two or three of the brushes sufficiently to permit a sheet of sandpaper to be inserted between the brushes and the commutator face with the abrasive side of the paper toward the brushes. Move the sandpaper along the commutator face in the direction from the heel of the brush to the toe; release the brush pressure as the paper is drawn back. It is important to keep the paper down on the commutator face to avoid rounding the edges of the brushes. The brushes in one side of compounding and commutation. In a generator, the armature current reduces or increases the main field magnetization, depending upon whether the brushes are ahead of, that is, shifted in the direction of rotation of, or behind the true neutral point, thus having considerable influence on the compounding. To prevent sparking, the brushes must be held in such a position that the armature coils short circuited by the brushes are under the influence of the

commutating poles. Occasional shifting from an exact center to produce slight changes in compounding is permissible. Even the most careful setting with a tram is subject to slight errors, and, for a final adjustment, slight changes in brush position may be necessary. secured to the frame. The rigging can now be rotated with a wrench.

On the other type machines, the rigging is rotated by removing the dowel which secures the yoke and inserting a steel bar in the holes provided on the rim of the yoke.

If a brush rigging has been completely disassembled, it will, of course, be necessary after assembly to locate the proper setting of the yoke. On all machines, the mechanical neutral is determined by the factory marks on the armature slots and commutator bars. Rotate the armature until two slots, which are marked, are equidistant from the center lines of two cominutating poles. Set the brushes of the stud between the two commutating poles at the center of the group of commutator bars which are marked on the ends. This will be over the center of the bar which is stamped with an identifying mark. The setting obtained in this way is approximate only, and must be checked by observation of the machine under load.

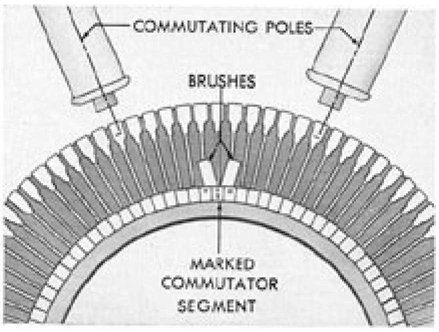


Figure 7-7. Factory mark on armature slots and commutator bars.

e. Rotating the brush rigging. Geared brush yokes used on General Electric machines are rotated by means of a pinion gear and wrench which are supplied as special tools. First, the upper cover on the side of the machine on which the yoke clamping arm is located must be removed. Next, the clamping arm is removed, the clamping bolt at the top of the yoke loosened, and the two flexible

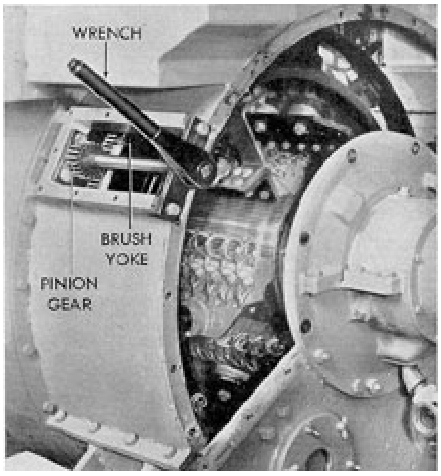


Figure 7-8. Wrench and pinion gear installed for rotating G.E. main motor brush rigging.

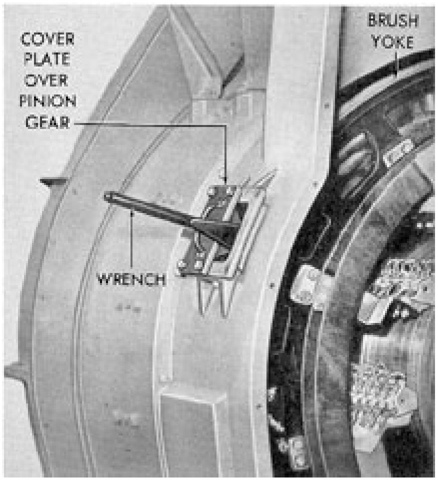


Figure 7-9. Wrench and pinion gear installed for rotating G.E. main generator brush rigging.

connections disconnected. The pinion is engaged with the gear teeth on the yoke and the pinion bracket

7A10. Care of commutators. a. General. Successful operation and long life of a machine depend largely on keeping the commutator surface clean and free from oil and dirt. This does not mean that a commutator should be kept bright and shiny. The proper color of the commutator after the machine has been run for some time should be uniformly medium or dark chocolate.

The commutator should be wiped occasionally with a piece of dry canvas. Waste or soft linty material must never be used. Oil, vaseline, or any of the so-called commutator compounds must not be used.

Sandpaper should be used lightly on the commutator, if at all, and emery cloth must never be used. Emery is a metallic conductor and, if lodged between segments, causes short circuits. If it does become necessary to use sandpaper to smooth a commutator, the paper should be fitted in a wooden block, shaped to the curvature of the commutator.

If the mica between the segments becomes higher than the copper, a hacksaw blade with the set ground off may be used for undercutting the mica. Good judgment should govern the frequency of this treatment; material used for wiping may be wound around a block and held against the commutator.

When in service, the commutator should maintain a dull polished surface. Blackening of all the bars indicates poor adjustment of the commutating field or incorrect brush pressure. Blackening of groups of bars at regular intervals may be due to the same cause or to poor brush contact. Blackening at irregular intervals indicates a rough or eccentric commutator that can be corrected satisfactorily only by stoning or cutting. This is a major repair and is usually performed by a tender or at a naval shipyard.

b. Brush vibration and sparking. Noisy brushes are generally the result of a rough commutator or too much clearance between the commutator and brush holders. Under some conditions, brush vibration accompanied by noise may appear at light loads. This is characteristic of some brushes and will disappear as soon as the brushes carry appreciable current. Brush vibration frequently causes sparking. Sparking of any kind should be watched closely to determine whether or not the bars are being damaged.

Due to slight mechanical unbalance, commutators may possibly run with an eccentricity of several thousandths of an inch at

undercutting the mica too frequently makes the slots too deep and permits a dangerous amount of carbon dust to collect in the undercut. After cutting down the mica, it is desirable to bevel the corners on the bars very lightly and to sand the commutator lightly to remove any rough spots from the edges of the segments.

A freshly turned commutator, or one on which the surface has been renewed, should be run under light load for approximately 24 hours. The commutator surface should then have a uniform polish. During the initial period of running, the commutator surface should be wiped with dry canvas at frequent intervals in order to remove any carbon deposit. Do not use waste or other linty material. No lubricants of any kind should ever be applied to a commutator. The brushes are self-lubricating and may leave a soft black deposit on the commutator when first placed in service. This deposit should be wiped off. The dry canvas or other nonlinty some speeds. This is not necessarily cause for concern, unless other damaging effects are noted. No attempt should ever be made to tighten or loosen the commutator clamping bolts for any reason.

c. Machine vibration. The source of any appreciable vibration of a machine should be located and corrected. A small amount of vibration may be expected from the diesel engine, but since all rotating parts of the generator are carefully balanced before installation, any existing vibration is usually the result of shaft misalignment. Newly fitted oil seals which rub on the shaft may also cause vibration.

7A11. Air gaps. Shims are provided between the poles and the frame for adjustment of the air gaps. The normal air gap for the main and commutating poles varies in generators of different manufacture. Refer to the manufacturer's instruction book for specific dimensions. When assembling any pole, the air gaps of the other

poles on the same machine should be measured at the same time and the loose pole set to agree.

In measuring the air gap, it is important that the poles be concentric about the armature. In case all poles are removed at once and reassembled, the air gap should be set to the factory specifications if a tapered gage is is low. The standby pump is also used to pre-lubricate the bearings after a shutdown. The bearings of direct drive motors are lubricated from separate motor-driven pumps. The pump controllers have a selector switch by which the pumps may be run at slow speed in order to obtain the quietest operation. This condition should never be used at shaft speeds in excess of 80 rpm. The oil flow at

used, and to shipyard readings if feeler gages were used originally, and are being used again. The air gap of a pole should be recorded, preferably before removal, with gages that are to be used for reassembly and the gap then reset to the original setting. Air gaps must be measured over a tooth on the armature which has been scraped clean of varnish. The location of this tooth is indicated by a mark on the armature next to the core on each end. Measurements are made by rotating this tooth under each pole, measuring from the same tooth to the pole in each case. The frame head supporting the bearings and the bearing housing are doweled after the air gaps have been adjusted at the factory. In adjusting the air gap, it is not necessary to allow for movement of the shaft in the bearings due to rotation. The air gaps are sufficiently large so that normal bearing wear will not have any influence on the operation. It is more important that all the air gaps be uniform than that their average be equal to the designated nominal value.

The commutating poles are provided with both magnetic and nonmagnetic shims. Whenever they are removed, the same thickness of nonmagnetic shims should be replaced as were removed.

7A12. Bearings and lubrications. a. Main motor bearing lubrication. The bearings of geared motors are fed from the reduction gear lubrication system. The pressure supplied by the main pump is adequate for full speed should be approximately 1 1/4 gallons per minute for the journal bearings and 2 1/2 gallons per minute for the thrust bearing.

b. Main generator bearing lubrication. The main generator bearings are the same type as those used on the main motors but they are lubricated from their respective main engine lubricating systems. The bearings are designed to operate with a 10 to 15 psi oil pressure at the bearing. Flow through the bearing should not be less than a quart per minute at normal speed. Any pressure that results in the required flow is satisfactory. Possible plugging is avoided by the size of the oil feed lines and the openings in the bearings which are not less than 3/16 in. in diameter. The flow of oil in passages of this size is not limited sufficiently at practical feed pressures. A bypass is, therefore, installed in the piping to divert a part of the flow around the bearings in order to prevent overlubrication and the possibility of excess oil entering the generator.

c. Temperatures of oil and bearings. The temperature of oil supplied to the bearings should not exceed 130 degrees F. The maximum safe operating temperature of the bearings is 180 degrees F.

d. Causes of overheated bearings. Overheated bearings may result from a number of different causes, among which the following are most frequently found:

1. insufficient oil

lubrication down to the dead slow speed (38 propeller rpm). When operating at dead slow speed the oil pressure is extremely low. However, if a continuous flow of oil can be observed in the oil sight flow indicators, the bearings are adequately lubricated. The standby lubricating oil pump is used to replace the main pump when the oil pressure drops below 5 pounds, at which time an alarm warns the electrician on watch that the pressure

2. inferior grade of oil
3. dirt and grit in oil
4. clogged oil lines
5. poorly fitted bearings
6. bearings too tightly set up
7. scratched or corroded journals
8. conduction from overheated electrical parts
9. misalignment of shafting

Dirt may cause the oil sight glass to indicate oil when none is present. A clogged top vent will have the same effect. Lack of end play will cause binding or heating, the trouble becoming aggravated as the shaft expands. A bent shaft will cause vibration and grinding at the journals. All of these troubles should be guarded against by frequent, intelligent inspections. Until a machine is available for overhaul, overheating may often be checked by the use of a liberal supply of fresh, cool oil, or in an emergency, by the use of water. The electrical parts should be kept clear of either oil or water.

c. Removal of bearings. The commutator end bearing housing on generators and motors is enclosed by a cover plate which must be removed to gain clearance for lifting the bearing housing over the bearing. Lifting jacks are provided for lifting the rotor slightly. This permits rotating the lower half of the bearing to the

frequently as necessary to provide an unrestricted flow of water.

b. Prevention of moisture condensation. Condensation of moisture in the air cooling system must be prevented in order to avoid the possibility of water being carried into the generator or motor and deposited on the windings. Since it is difficult to determine accurately the temperature at which condensation will occur, the best practice is to adjust the cooling water flow until it is just sufficient to maintain the temperature of the air out of the machine at about 10 degree F below the maximum allowed in the manufacturer's instruction book.

CAUTION. Whenever the load is changed, the temperature should be checked immediately and the cooling water adjusted accordingly. Failure to do this will cause great changes in the injection temperature of the cooling water.

top of the shaft for removal. During removal, care must be taken to prevent damage to the external surface of the bearing which fits the housing. The lifting jack must be slacked off after the bearing is replaced. Serious damage will result from neglect of this precaution.

7A13. Cooler maintenance. a. Cleaning. Periodic cleaning of water tubes is necessary to remove any foreign matter carried in by the cooling water. Access to the tubes on all types of coolers is obtained by removing the water boxes or headers. The interior of the tubes may be cleaned with nonabrasive brushes, rubber plugs, compressed air, or by any standard approved method used for cleaning condenser tubes.

Strainers in the water inlet line and the inside of the core tubes should be cleaned as

c. Control of cooling water. The flow of cooling water is controlled by valves and, in the case of the motors, also by speed control of the pump. The piping is arranged so that any cooler section may be cutout and the machine operated on the remaining section or sections. When operating on reduced coolers, the machine temperatures must be watched closely and the load reduced if necessary.

d. Zinc plates. Each cooler section contains protective zinc plates which protect the cooler tubes from the electrolytic action caused by salt water. These plates must be inspected at regular intervals and replaced when approximately 75 percent of the plate has been dissolved. Neglect of this inspection and renewal leads to serious cooler deterioration and possible damage to the motor or generator through the leakage of the cooling water into the machine.

B. CABLES

7B1. Insulation resistance measurements of cables. a. General. The primary purpose in making insulation resistance measurements of cable installations is to determine the condition of the cable in order that deterioration, which would result in eventual failure, may be discovered and remedied. Insulation resistance and methods of measuring its values are explained in Sections 7A2 and 7A3.

b. Factors affecting resistance values. The following factors must be considered in measuring insulation resistance of cables:

1. Other apparatus connected. Any equipment connected in the circuit when a measurement is made will result in a reading that will include the connected equipment. For example, when measuring the insulation resistance of the positive cable connecting a generator to a

switchboard, the cable should be disconnected at each end. If this is not done, the measurement will include the insulation resistance of the bus work, all apparatus connected to the bus, the generator, and the negative cable. Since the insulation resistance of this other apparatus is in parallel with that of the cable, the measured value of the combination may be considerably below the value that would be obtained if the cable were disconnected and measured separately.

For convenience, initial measurements may be made with the cable only partially isolated by opening switches, circuit breakers, or other disconnecting devices in the circuit. If the value then obtained is satisfactory as compared to previously recorded values that were obtained under the same conditions, or to limiting values, no further isolation of the cable will be necessary. Otherwise, it will be necessary to completely disconnect the cable and measure it alone before a conclusion can be drawn as to its condition.

2. Total quantity (number and length) of cable. When insulation resistance of cables is to be measured, its length must be taken into account. The total insulation resistance of a particular length of cable is the resultant of a number of small parallel individual leakage paths distributed along the cable sheath. In order to have a common unit of comparison, the cable insulation should be expressed in ohms or megohms conductor cable are based on the insulation resistance between all the conductors connected together and the sheath or ground. Thus, when reference is made to total length of multiple conductor cable, it means the length represented by the sheath and not by the sum of the length of individual conductors within that sheath. For example, the total length of 300 ft of MHFA-7 (7-conductor cable) is 300 ft, not 7 times 300 ft. Consequently, the insulation resistance per foot with all conductors connected together, is 300 times, not 2100 times, the measured value.

3. Type of cable. Insulation resistance varies considerably with the nature of the insulating material employed and the construction of the cable. It is possible, therefore, to judge the condition of a cable as determined by its measured insulation resistance only when it is considered in relation to the typical characteristics of the particular type of cable in question. The heat and flame resistant cables (type HF series) are now in general use. The curves shown in Figure 7-10 are applicable only to the type specified.

4. Temperature. Fairly accurate temperature measurements on the sheath of the cable must be made in order to permit a reliable interpretation of the insulation resistance measurements. The temperature should be measured by means of thermometers, attached to the cable sheath, or armor, at several points along the length of the cable. An average is then made of these values. The

per foot of length. This is determined by multiplying the measured insulation resistance of the cable by its total length. It should be noted that in so far as insulation resistance measurements are concerned, it makes no difference whether the cables are in series or in parallel, and consequently the total length should include the sum of all the lengths of cable connected at the time of measurement. For example, if 2 cables, each 100 ft long, are connected together, even at only one end, at the time of measurement, the total length is 200 ft and the insulation resistance per foot is 200 times the measured value. The foregoing should not, however, be confused with the total length of individual conductors when considering multiple conductor cable. For convenient comparison purposes, the data applicable to multiple thermometer bulb should be placed in direct contact with the sheath, or armor. Scrape away the paint at the point of contact. Hold the thermometer in place with pads of felt or other, heat insulating material placed over the bulb and secured with tape. The number of thermometers used and their location should be such that they indicate a representative average of the sheath temperature of the entire cable being measured.

The effect of temperature on insulation resistance of SHFA and SHFL type cables is graphically illustrated by the curves shown in Figure 7-10 which show the resistance changes which may occur in the normal operating temperature range as measured at the cable sheath.

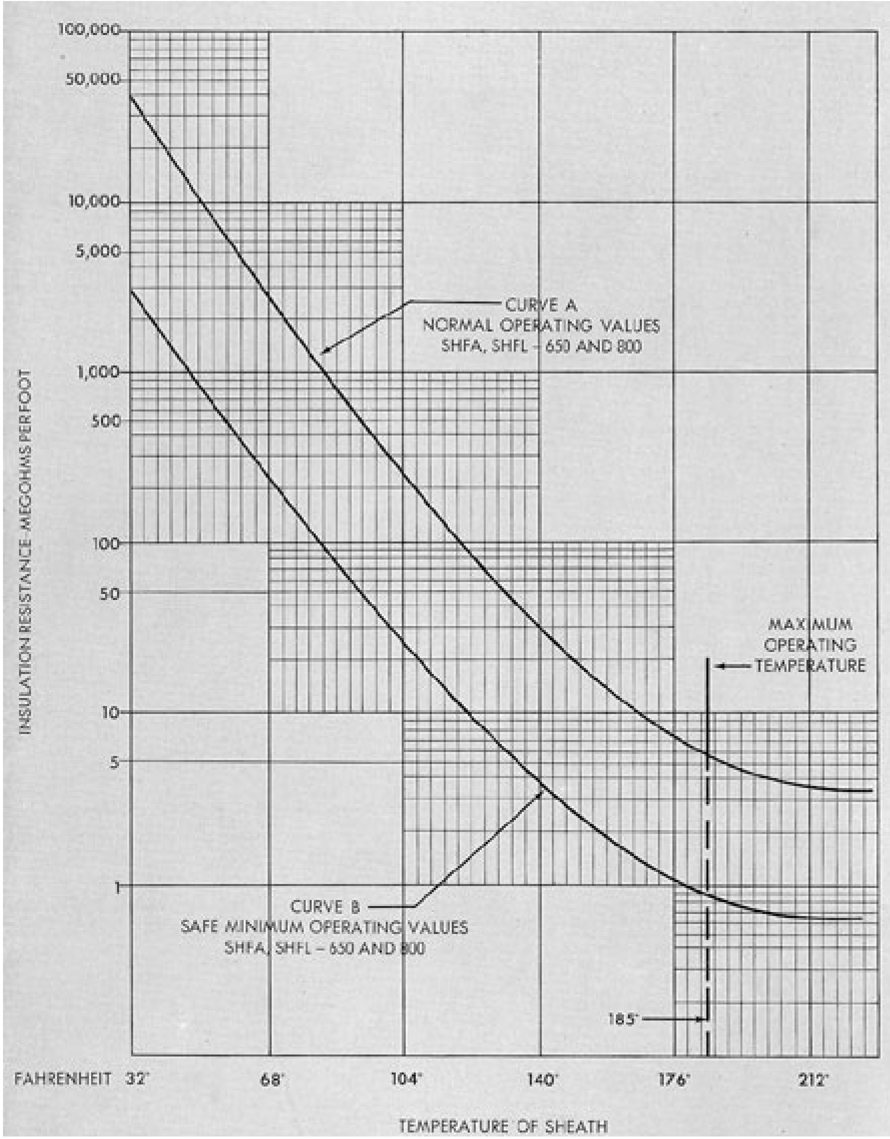


Figure 7-10. Insulation resistance vs. sheath temperature, SHFA, SHFL, sizes 650 and 800.

Curve A of Figure 7-10 is the characteristic curve of insulation resistance and temperature for normal types SHFA and SHFL, size 650 and 800 cables. In referring to the curve, it should be noted that the insulation resistance falls rapidly with increase in temperature. Curve B of Figure 7-10 indicates a safe minimum insulation resistance for the cables, when used at submarine propulsion voltages.

c. Procedure. The procedure in measuring insulation resistance should be as follows:

should be measured from all conductors connected together to the armor, or to the metallic structure, or ground, to which the cable is attached if the cable is without armor. Measurements should also be made from each conductor to every other conductor. For example, in a 3 conductor cable this results in 4 measurements from armor or ground to conductors 1, 2, and 3 connected together; from conductor 2 to conductor 3. The lowest of these values should be used as the measured value.

1. Disconnect the cable from other equipment, in so far as practicable, and make a record of the connections remaining.

2. Measure the average sheath temperature.

3. Ground the cable for a few seconds to remove any static charge.

4. Measure the insulation resistance by means of a suitable instrument.

For single conductor cable (SHFL, SHFA, SDGA) there is but one insulation resistance to measure; that between the conductor and armor of lead sheath. For multiple conductor cables (MHFA, THFA, etc.) the insulation resistance

5. Determine the total length of the cable in the circuit.

6. Multiply the total length by the measured resistance, thus obtaining the resistance in megohms per foot.

7. Compare the measured megohms per foot with the minimum safe megohms per foot indicated by the applicable curve at the measured average sheath temperature.

8. If previous measurements were made of exactly the same installation with the same equipment in the circuit and at the same temperature, compare the present resistance values with the previous values and note what change has occurred.

C. AUXILIARY MOTORS AND MOTOR GENERATOR SETS

7C1. General maintenance of auxiliary motors and motor generator sets. a. Cleaning. The interior and exterior of the machines must be kept clean at all times. Inspect the machines daily for presence of dirt, oil, and moisture, and wipe the machines thoroughly if such foreign matter is found.

b. Insulation resistance. Moisture on the commutator, armature, or field coils causes leakage paths that lower the insulation resistance and result in a ground. Periodic checks of the insulation resistance should be made and recorded, following the same general procedure as outlined for main motors in Section 7A3. Since no specific acceptable values can be established such it can be determined when cleaning, drying, or other servicing of the machine is necessary.

If a test indicates that the insulation resistance is below an acceptable value, all parts should be wiped with clean cloths. Do not use a cloth that will deposit lint in the windings. If the insulation resistance remains low, the windings should be cleaned with an approved solvent solution. The commutator heads and cross connectors should also be thoroughly cleaned.

Dry the windings as outlined in the section that follows (7C1c) until the insulation resistance becomes constant; then coat windings and adjacent parts with a high-grade air-drying varnish. Never apply

periodic tests are useful in detecting weaknesses of insulation or accumulations of moisture or dirt. Then by comparing readings with those previously recorded under approximately similar conditions of temperature and humidity, varnish over damp or dirty parts, and do not depend on insulating varnish alone to increase the insulation resistance. All parts must be cleaned and defects repaired before varnish is applied.

c. Drying windings. Windings may be dried by circulating hot air through the machine by means of a fan. A spare heater or a bank of lights may be used as the source of heat. Care should be taken to see that the heat is distributed evenly so that all parts will have the same temperature and dry evenly.

Drying can also be accomplished by passing reduced current through the shunt field coils. It should be noted, however, that short circuits may develop in the coils if this method is used while the coils are wet or actually grounded.

When drying a coil with power applied, check the temperature of the coils every 15 minutes for a few hours. If the temperature increases to a point where the coil is too hot to touch, shut off the current.

NOTE. Do not continue drying after the insulation resistance becomes constant. If insulation resistance is still low, determine which parts of the machine are defective and make any necessary repairs.

d. Armature. It is important that air spaces between coils be open for free circulation of air. This is condition. Use special insulating compounds for these parts. Keep the undercut between copper segments clean. This will prevent burning between bars and possible short circuiting of armature coils.

Do not sandpaper or stone commutators unless their condition makes it necessary. Never use emery cloth or paper on a commutator. If sanding or stoning should be necessary, make sure that the paper or stone fits the surface of the commutator.

After the machines have run for a short period, commutators usually acquire a dull brown finish. This is the proper surface. Do not try to keep the commutators bright and shiny. If the mica between commutator segments becomes higher than the copper, the slots should be undercut. This is easily done with a hacksaw blade which has the set ground off. Excessive undercutting with a sharp instrument must be avoided because it will wear down the mica to such a point that an excess amount of carbon dust may collect in the undercut. After the mica has been cut down with a saw blade, file, or other instrument, it is desirable to sand the commutator

also true of the openings between the shaft and core plates. Do not allow dirt or other foreign material to accumulate on the armature, particularly in locations where it will restrict the free circulation of air. It is of major importance that no oil or dirt accumulate above the commutators. Large creepage distances are provided between the commutator bars and heads. Keep this portion dry and occasionally coat with special insulating compound supplied for this purpose. Armature coils should be cleaned regularly and should occasionally be thoroughly dried and varnished in accordance with general instructions. A vacuum cleaner with a small inlet is effective in cleaning between the coils, and is much more desirable than compressed air. Steel banding wire should be checked regularly and replaced if any bands show signs of defect.

e. Commutators. Successful operation and the longevity of machines depend largely on the degree to which the commutators are kept clean and free from oil or dirt. Wipe the heads and ends of V-rings frequently to keep them in good lightly to remove any burrs on the edges of the copper segments.

If commutators have high bars or are rough, they should be ground smooth, otherwise the condition may cause excessive sparking and heating of the commutators or severe burning of the bars and possible loosening of the armature leads. Grinding should be done at as high a speed as practical, and with extreme care. Make several light passes over the commutator. When finished, undercut the mica and sand the commutator lightly. Canvas should be fitted around the armature so that copper dust will not enter the spaces between the windings. If practical, a vacuum cleaner should be placed in a position to collect the flying dust. When finished, the machine should be thoroughly cleaned. Compressed air should not be used for this purpose as it will blow the copper dust through the entire machine. Commutator clamping nuts should not be disturbed.

f. Main poles and coils. Main poles are

held to the motor frames by bolts that may be removed with standard wrenches. The coils and adjacent parts should always be kept clean. Dirt must not be allowed to collect between the coils and magnet frames. If dirt cannot be readily removed, release the holding bolts and If it is impossible to remove readily the dirt between the plates and the frame, the poles may be released in the same manner as the main poles. Coils are dipped in insulating compound and baked and are therefore, a solid piece. Disassembly of a coil from a pole may be easier if the coil is heated

wipe the coils and frames with a cloth. Dry the coils, coat with air drying insulating varnish, and tighten the bolts. Make certain that the bolts are thoroughly tightened, and that there is no misalignment of the poles.

If a coil should become damaged, remove it, together with the pole piece, from the machine. This can be done without removing the armature. When removing the coil from the pole, or when reassembling, do not damage the sheets of insulation wrapped around the pole.

Should it be necessary to replace any of the taping, dry the coil thoroughly and coat it with air drying insulating varnish before retaping. Never apply varnish to a damp coil, for it will tend to seal in the moisture and may cause trouble. When removing a coil, be sure to check the air gap before releasing the holding bolts. Then disconnect the cross-connectors and check the markings to make certain that the connectors will be replaced in their proper positions. When the bolts have been released, observe the number and thickness of the shims. Withdrawing or replacing a coil should be done very carefully so that the pole will not damage the armature. The use of a sheet of pressboard rubbed with paraffin and inserted in the air gap often makes this operation easier.

g. Commutating poles and coils. Commutating poles are held in the same manner as the main poles. The method of removing after it has been removed from the frame. Coils are fitted on the poles from the frame side so that it is unnecessary to remove the pole shoes. The method of removing a commutating coil is similar to that of removing a main field coil. When tightening cross-connectors to terminals of a commutating coil, use a feeler gage to insure full contact. Commutating poles are provided with both magnetic and nonmagnetic shims. The same thicknesses of both types should be replaced as were removed.

h. Brushes and rigging. The brush rigging is of rigid construction in order to eliminate vibration. All studs must be kept tight. Insulator plates must be cleaned regularly. The machines should never be run until the brush rigging is locked in its proper position.

Brush holders should be kept in their original position so that they are square with the commutator segments and so that the distances between the brushes around the commutator are equal. Brush holders are removable and fit in grooves to assure proper alignment.

The brushes furnished for each application are of a type and grade selected to give best operation. The type and grade should not be changed without consulting the manufacturer of the equipment. Brushes should not be loose in the holders, neither should they be so tight that they do not move freely. New brushes should be sanded to fit the surface of the commutator. Care must be taken during this operation to make sure that carbon dust is not blown through the machine.

and replacing a commutating coil is similar to that for a main field coil.

The voltage drop across any one commutating coil will be very low, so there is little or no chance of short circuited turns. However, the voltage to ground may be practically as high as the line voltage. Also, the commutating coils are of taped copper bar. Therefore, it is important that no dirt collect on the insulating plates or lodge between the plates and magnet frames.

Spring tension on the brushes should be approximately 2 psi of brush surface. If brushes spark, due to a rough commutator, little or nothing is accomplished by setting the springs for higher tension. Continuous operation under these conditions will cause excessive heating of the commutator which may result in loosening of the armature leads. Correct the trouble at its source.

D. AUXILIARY CONTROL EQUIPMENT

7D1. Magnetic contactor starting panels. a. Cleaning and inspection. Control equipment should be cleaned and inspected regularly to prevent breakdowns or serious shutdowns. Dust that collects on the working parts of a controller must be removed. Excessive wear of moving parts can be avoided if parts are kept free of foreign matter.

b. Lubrication. The armature lever shaft of contactors should be lubricated occasionally. A light engine or machine oil should be used. The quantity of oil used should be kept to an absolute minimum so that the oiled parts do not become dust collectors. Oil must not be allowed to collect on the sealing surfaces of operating magnets since improper operation of the device will result.

although badly oxidized, can still make good contact.

The main and auxiliary contactor contact surfaces must be kept clean and uniformly bearing. The contact springs should be kept at an even tension or replaced if found defective. Protective overload and no-voltage devices should be inspected and tested periodically. On these tests, the proper operation and sequence of the contactors should be noted. The need for minor repair or adjustment to one contactor will often disable a panel. The flexible connector terminals should be kept tight and other possible sources of open circuits watched.

d. Arc chutes. On contactors equipped with blowouts, the arc shields should be replaced before the material is burned away

c. Contacts. Contacts should be renewed before their wear allowance is completely gone. When copper contacts become badly roughened or burned, they should be smoothed off with a fine file, taking care to remove only as little copper as is necessary to reestablish good contact. Silver contacts should not be filed except in extreme cases of roughness. A silver contact,

enough to allow the arc to touch the blowout pole piece.

e. Insulation. The insulation on wires and coils may sometimes be damaged due to vibration and friction against other parts. Parts with damaged insulation should be reinsulated as soon as the damage is discovered, and wherever possible, the cause of the damage should be removed,

E. PANELS AND SWITCHBOARDS

7E1. General maintenance of panels and switchboards. Panels and switchboards should be wiped frequently with a soft brush having no metallic binding. If it is necessary to clean off anything other than dust, a soft flannel cloth or a piece of chamois should be used. Cotton waste or cloths that leave lint must not be used.

Frequent examination must be made to insure that all connections are tight.

The condition of the wires behind the board should be checked periodically.

The tendency of the ship's structure to weave sometimes causes enough movement of the wires behind the board to result in their abrasion and consequent breakdown.

Surface moisture must be kept at a minimum on all panels to hold up the circuit insulation resistance readings. Its presence on a panel will often account for low circuit insulation resistance readings. If it becomes necessary to remove moisture, use a flannel cloth.

Alcohol must never be used for cleaning panels. This substance is not only inflammable, but its use will break down the finish surfaces of panels and of the instruments mounted on them.

The use of an approved lacquer is recommended since it not only improves appearance, but also produces a polished surface which does not absorb and hold moisture.

F. HEATING UNITS

7F1. General maintenance.

of carbon is found, the blades

Before any attempt is made to work on a heater or switch, all power lines to the unit must be disconnected.

Immersion type heating units used in lubricating oil heaters should be removed and inspected periodically for the presence of carbon on the heater blades. This deposit is caused by continuous contact with oil. If an accumulation must be scraped clean, then reinstalled.

Contacts in the terminal box and switch should be checked and tightened if necessary.

Care must be taken to see that immersion type units are not turned on unless they are immersed. The elements burn out quickly when current is applied to a dry unit.

PART 2

INTERIOR COMMUNICATION, FIRE CONTROL, GYROCOMPASS, AND UNDERWATER LOG SYSTEMS

8
CIRCUITS AND SWITCHBOARDS

A. CIRCUITS

8A1. Description. Interior communication (I.C.) systems in a submarine provide the means of maintaining contact, transmitting orders, and relaying indications of the condition of certain machinery or other parts of the ship, to and between various stations in the ship. Each of the systems is designed to perform a specific function such as transmission of voice, transmission of an indication of heat or pressure, the degree of rotation of some device, the open or closed state of a valve, or simple bell or light circuit. Others, such as the underwater log and compass, furnish vital navigational information.

The majority of the systems are electrical and automatic in operation. Some, such as the motor order telegraph system are manually operated but include an electrical circuit for the actual transmission of the order to another part of the ship. Some of the systems operate on alternating current, others on direct current; still others, such as the tachometer and sound-powered telephone systems

General alarm system (circuit G)

Diving alarm system (circuit GD)

Low-pressure lubricating oil and high-temperature water alarm system (circuit EC)

Shaft revolution indicator systems (circuit K)

Gyrocompass system (circuit LC)

Auxiliary gyrocompass system (circuit XLC)

Motor order telegraph system (circuit 1MB and 2MB)

Marker buoy system (circuit BT)

General announcing system (circuit 1MC)

Submarine control announcing system (circuit 7MC)

Rudder angle indicator system (circuit N)

Bow and stern plane angle indicator system (circuits NB and NS)

Auxiliary bow and stern plane angle indicator system (circuits XNB and XNS)

operate on self-generated current.

The various systems and their components are described in this and following chapters.

The I.C. systems of a modern fleet type submarine usually consist of about 24 circuits. With few exceptions, they are supplied with power through the I.C. switchboard located in the control room.

The following is a list of important I.C. circuits and their circuit designations:

Telephone call system (circuit E)

Engine governor control and tachometer system (circuit EG)

Battle telephone systems (circuits JA and XJA)

Engine order control system (circuit 3MB)

Dead reckoning tracer system (circuit TL)

Collision alarm system (circuit CA)

Main ballast indicator system (circuit TP)

Hull opening indicator system (circuit TR)

Underwater log system (circuit Y)

Bow plane rigging indicator system

In addition, the following circuits which are not part of the I.C. systems, are supplied through switches on the I.C. switchboard:

Torpedo data computer (circuit GA-1)

Torpedo data computer (circuit 17GA-1)

Torpedo firing (circuit 6PA)

Torpedo ready lights (circuit 6R)

Target designation system (circuit GT)

8A2. Systems requiring alternating current. The following systems require alternating current for operation:

Self-synchronous operated motor order telegraph and indicator systems (for main propulsion orders)

Self-synchronous operated diving plane angle indicators (bow and stern planes)

Self-synchronous operated rudder angle indicator system

Hull opening and main ballast tank indicator systems

Engine governor control system (direct current on latest submarine)

Torpedo data computer (circuit GAl)

8A3. Systems requiring direct current. The following systems require direct current for operation:

Marker buoy system

Hydrogen detector

Lubricating oil (low pressure) and circulating water (high temperature) alarm systems

Telephone selective ringing system

General announcing systems (alarm signals and voice communication)

Self-synchronous operated underwater log system

Self-synchronous operated propeller shaft revolution indicator system

Target designation system

Engine order indicator system (alternating current on older submarines)

Searchlight

Auxiliary gyrocompass

Torpedo data computer (17GA-1)

Torpedo firing

Torpedo ready lights

Engine governor control system

Auxiliary bow and stern plane angle indicating systems

Resistance thermometer systems

Gyrocompass system

B. INTERIOR COMMUNICATION AND ACTION CUTOUT SWITCHBOARDS

8B1. Interior communication switchboard. a. Description. The I.C. switchboard is usually located on the starboard side of the control room. The switchboards on the latest type submarines are equipped with snap switches and dead front fuses, with blown fuse indication, mounted directly below or on either side of each switch requiring fuses. Earlier type submarines used knife switches with fuses mounted immediately below each switch.

b. Source of power. The alternating current power supply to this switchboard is obtained from the I.C. motor generators which are comprised of either 250-volt d.c. motors and 120-volt a.c. generators, or 120-volt d.c. motors and 120-volt a.c. generators, depending upon the equipped with an emergency supply obtained from a center tap off the battery through a double throw switch, for use in the event of failure of the lighting motor generator set.

The direct current power supply to the switchboard comes from the lighting system. An auxiliary supply of direct current for the gyro compass and torpedo data computer may be obtained from a rectifier which receives its power supply from the alternating current bus.

Fused switches are supplied for the primaries of each of the two 120/8 volt transformers for the 6-8 volt circuits, and for the searchlight. One spare fused switch is provided, wired into the direct current bus, and 2 spare

type of installation. The former would take its power directly from the batteries, the latter from the lighting system. If the supply is taken from the lighting system, the installation is also switches are wired into the alternating current bus.

Figure 8-1 is a simplified diagram showing the I.C. power supply system and controls.

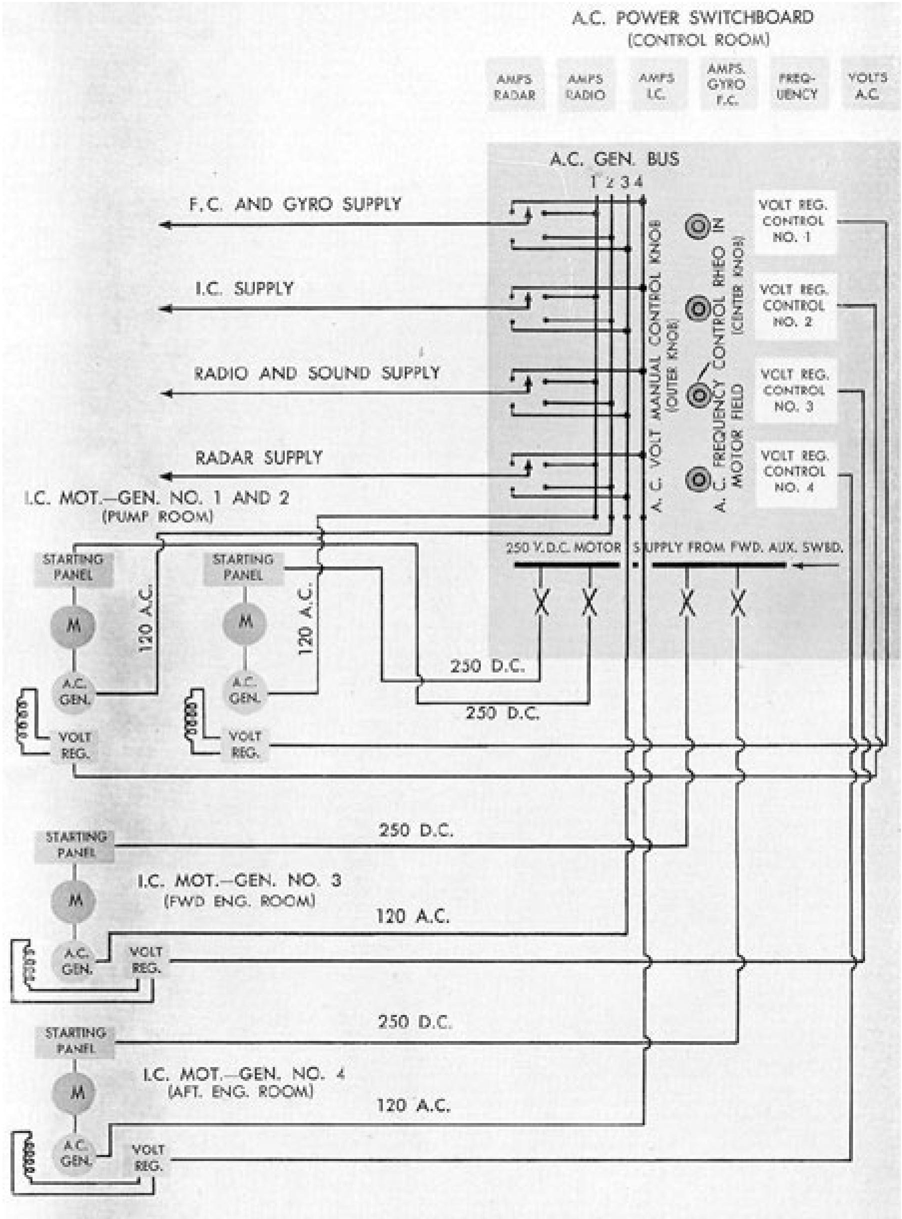


Figure 8-1. Simplified diagram of I.C. power supply.

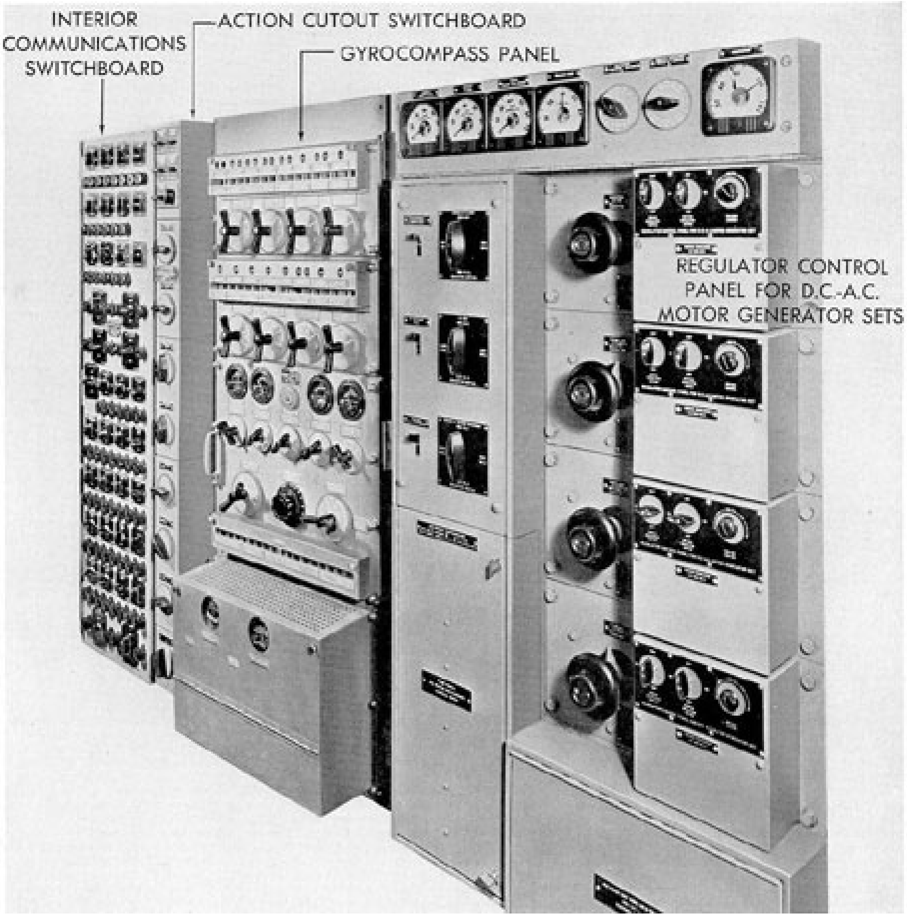


Figure 8-2. I.C., gyro, action cutout and I.C. motor generator switchboards, latest type.

8B2. Action cutout switchboard. The action cutout switchboard on the latest fleet type submarines is mounted adjacent to the I.C. switchboard. The action cutout switchboard usually has 6 snap switches (5 active and 1 spare) which are provided to cut out general announcing circuits from the bridge and conning tower; and 8 rotary switches (7 active and 1 spare) to cutout and transfer the control and indicating stations of the various I.C. circuits between the bridge, the conning tower, and the control room.

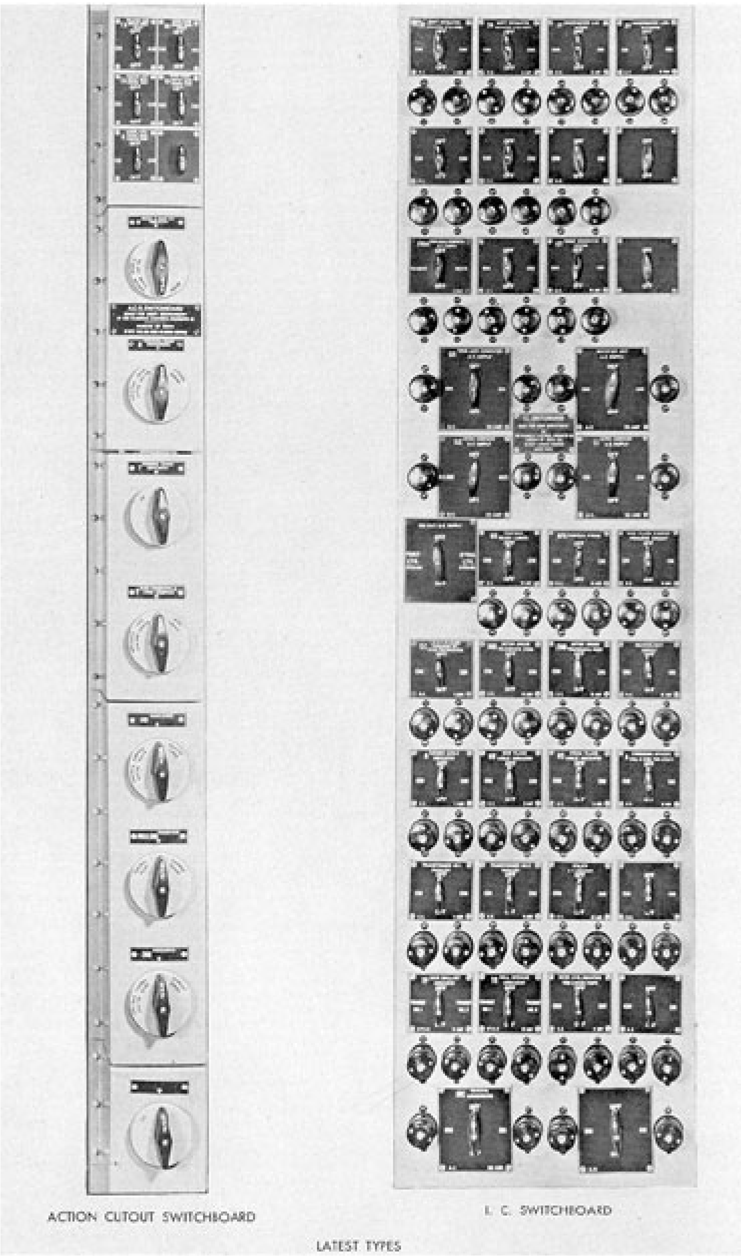


Figure 8-3. Action cutout and I.C. switchboards, latest type.

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9
AUTOMATIC A.C. FREQUENCY AND VOLTAGE CONTROL

A. MOTOR GENERATOR SPEED REGULATORS

9A1. Automatic motor speed regulator for d.c.-a.c. motor generator set. In order to maintain the frequency of the a.c. output of the d.c.-a.c. motor generator set within closely controlled limits, a speed regulator for the d.c. motor is required. The speed regulator is essentially an automatic, mechanical, governor-operated field rheostat. Its principal elements are a mechanical governor which acts as the sensitive element, and a field rheostat which is in series with the shunt field of the motor to be controlled.

The governor is coupled to the motor shaft and consists of balanced weights or flyballs, rotating about a common shaft. These weights are prevented from flying outward by pressure of the governor spring. As the speed of the motor increases, the pressure of the governor spring is overcome and the flyballs move outward until a balanced condition is again reached between the spring pressure and flyballs. The outward motion of the flyballs and the movement of the governor spring actuate an operating rod which in turn transmits its motion, through a motor speed. To provide a finer adjustment, a range spring that permits adjustment to within 5 percent of normal speed is connected to the actuating lever. This spring, due to its length and the location of its pivot pin, aids the action of the governor spring. It does not, however, exert enough force to interfere with the movement of the flyballs. Normally, the range spring should be set halfway between zero and maximum tension; and further adjustment, to obtain normal motor speed, should be made at the governor control spring.

To reduce hunting and provide stability to the operation of the regulator, an oil dashpot and a droop spring are coupled to the actuating lever. The dashpot consists of an oil-filled cylinder in which a piston operates. It is coupled to the actuating lever by means of a piece of flat spring steel. Whenever the actuating lever moves, the flat spring forces the piston to move, and since the oil tends to retard this movement, the tendency of the actuating lever to hunt is appreciably reduced.

The droop spring is attached to the actuating lever by means of a bracket. The position of the bracket and droop spring in

lever and bracket, to the sliding contact bar of the regulator field rheostat.

The field rheostat is of segment assembly (commutator) design. The segments are electrically connected to resistor plates. As the V-shaped carbon contact bar is moved across the segments, the resistance included between the two points of the V contacting the segments is short circuited, thereby increasing or decreasing the strength of the motor shunt field, depending upon the direction in which the contact bar is moved.

The speed at which the regulator operates is principally dependent upon the tension setting of the governor spring. This setting, how ever, cannot be sufficiently accurate to operate the regulator within the desired regulation relation to the actuating lever is such that the tension in the spring opposes the tension provided by the governor spring with a varying force, dependent upon the position of the actuating lever. A similar effect would be obtained if the droop spring were omitted, and the governor spring tapered (conical) in cross section. This is the case in many types of governors.

Regulator adjustments should be attempted only after a thorough study of the manufacturer's instruction book which outlines the correct procedures to be followed.

This regulator is shown mounted on the motor shaft on a motor generator set in Figure 9-1.

This type of governor is also used to regulate the speed of the d.c.-d.c. motor generators used for lighting on some vessels. Speed regulation in this case is used to control the voltage regulation and it becomes therefore a voltage regulator as well.

9A2. Operation. Prior to starting the motor generator set, the operator should make certain that the manual motor field rheostat is at the lowest speed (all resistance cut out), and that the manual generator field rheostat is at the lowest voltage end (all resistances cut in), also that the automatic speed and generator set should then be started and the speed of the set increased, using the manual motor field rheostat, until the frequency of the a.c. output voltage is approximately 62 cycles. The automatic speed regulator switch should then be put in the ON position. This places the automatic, speed regulator in operation. The manual motor field rheostat should now be returned to the lowest speed position.

In stopping, the load should first be removed from the generator, and the automatic speed regulator switch then turned to the OFF position.

voltage regulator switches are in the OFF position. The motor

9A3. Maintenance. Moving parts of the

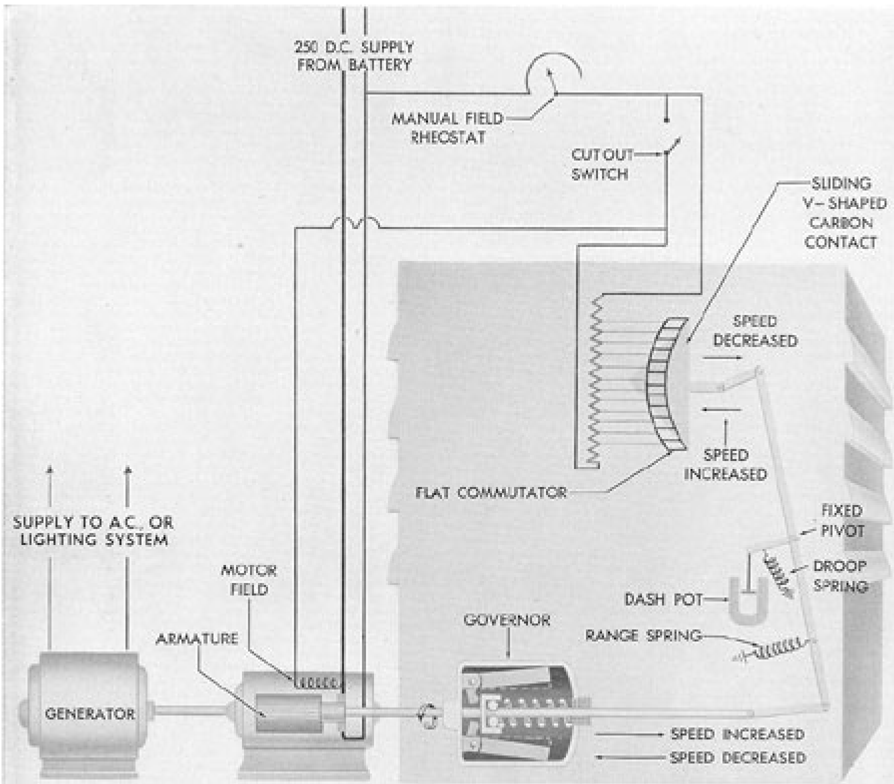

Figure 9-1. Speed regulator for lighting motor generator sets and interior communication a.c. motor generator sets.

regulator should be kept free and clean. The contact bar and the contact surface of the segment assembly should be inspected periodically. If the regulator has remained idle for any length of time, or if the contact surfaces have become rough for any reason, polish these surfaces. Use very fine sandpaper (8/0) and finish with crocus cloth. If the contact surfaces are so rough that the sandpaper alone will not produce a smooth finish, use a very fine file such as a contact point file, follow up with a fine-grade sharpening stone, and then finish with sandpaper and crocus cloth. The contact surface across the segments must be kept absolutely straight. Care should also be taken not to burr the segments while polishing, and no particles should remain in the undercut sections between adjacent segments. Neither the contact bar nor the segment assembly should ever be oiled.

In the event that it becomes necessary to renew any parts of the regulator that might disturb its operating adjustment, the manufacturer's instruction pamphlet should be studied carefully and the adjustment procedure outlined therein followed precisely.

B. ROTARY SOLENOID TYPE AUTOMATIC A.C. VOLTAGE

REGULATOR

9B1. Description. In order to maintain a constant a.c. line voltage in the output of the a.c. generator, a voltage regulator is required. The rotary solenoid type regulator is essentially a solenoid-operated, sliding contact, field rheostat. It consists principally of a sensitive rotary solenoid with a spring balanced plunger, a transformer, a dry disk rectifier, and a field rheostat which is in series with the shunt field of the a.c. generator whose voltage is to be controlled.

The rotary solenoid is energized by means of rectified current obtained from the generator through the transformer and rectifier. The plunger of the solenoid controls the excitation of the generator field by moving a V-shaped sliding contact bar across segments which are connected to the voltage regulator resistors. As the V-shaped contact bar is moved across the segments, the resistance between the two points of the V making contact is short circuited, thereby increasing or decreasing the strength of the generator shunt field, depending upon the direction in which the contact bar is moved.

Any change in the generator a.c. voltage causes a variation in the magnetic field strength of the solenoid and this in turn causes the solenoid plunger to move the sliding contact bar. At the normal voltage output of the generator, the magnetic field is of such strength as is necessary the plunger in its maximum clockwise position. When the circuit is energized, the magnetic field of the solenoid tends to move the plunger in a counterclockwise direction, putting the spring under tension. The spring tension, however, is adjusted so that at normal voltage, or midposition of the plunger, a balanced condition is attained between the tension of the spring and the strength of the solenoid magnetic field.

In the event that the a.c. voltage decreases in the circuit, the following action takes place:

1. The magnetic strength of the solenoid is decreased, allowing the spring to pull the plunger in a clockwise direction.

2. As the plunger moves in a clockwise direction, more resistance is shorted out of the generator field circuit. This increases the generator field strength and raises the voltage.

If, on the other hand, the load voltage rises, an action opposite to that described above takes place.

To reduce hunting in the system, two features are installed. One is a sealed oil dashpot arrangement mounted so that its piston retards any rotary motion of the plunger arm. The other is an electrical circuit consisting of an adjustable resistor so connected across the solenoid main winding that the direction of current through the circuit opposes that of the current supplied by the dry disk rectifier. Whenever the terminal voltage of the generator suddenly decreases,

to keep the plunger approximately in midposition.

A spring is attached to the plunger arm. When the circuit is deenergized this spring keeps the potential across this circuit is momentarily decreased, reducing the effect of the anti-hunt current opposing the main current.

This results in a less sudden reduction in the strength of the magnetic field of the solenoid than would be obtained if the anti-hunt circuit were not installed. Therefore, the effect of the circuit is to retard any sudden tendency of the plunger to move in a clockwise direction. If the terminal voltage of the generator suddenly increases, the effect of the anti-hunt circuit is to retard the sudden movement of the plunger in a counterclockwise direction.

In addition to the main winding on the solenoid, there is a compound winding. This winding carries a portion of the generator field current and is connected so that its magnetic effect opposes that of the main winding, resulting in a compounding effect. A bypass resistor is connected across the winding to serve as a means of adjusting the amount of compounding.

The range of voltage through which the regulator must operate is controlled by adjustment of the range control resistor. To attain approximately normal voltage, the initial adjustment of the range control resistor should be made with the regulator control rheostat in midposition. Final adjustment is then made by positioning the control rheostat.

It is to be noted that the tap on the secondary of the transformer is deliberately made off-center in order to introduce a slight unbalance of the magnetic field of the solenoid in operation and thus reduce the effect of static friction on the plunger.

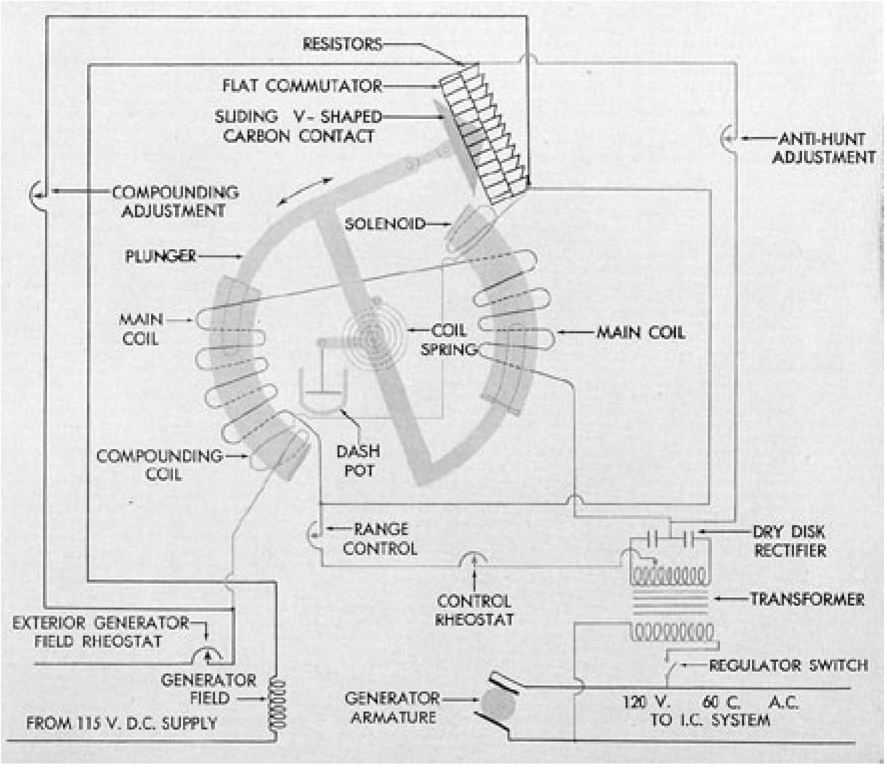

Figure 9-2. Schematic diagram of I.C. motor generator voltage regulator, rotary solenoid type.

9B2. Operation. After the motor generator set has been started and the frequency of the a.c. voltage regulated as outlined in Section 9A2, the output voltage of the generator should be manually adjusted to its rated value by means of the generator field rheostat. Then, with the automatic regulator control rheostat set approximately in its midposition, the regulator switch should be turned on and the manual generator field rheostat turned to the ALL RESISTANCE OUT position. The regulator now has control of the voltage and final readjustment of the voltage can be made by means of the regulator control rheostat.

In removing the regulator from control of the generator, the load should first be removed from the generator. The manual generator field rheostat should next be moved to cut all resistance into the generator. The automatic regulator switch may then be turned to OFF.

9B3. Maintenance. The same general procedures as outlined in Section 9A3 should be followed in maintaining this voltage regulator.

C. REACTOR TYPE AUTOMATIC VOLTAGE REGULATOR

9C1. Description. A reactor type automatic voltage regulator is essentially a series of electrical and magnetic circuits so connected that they the exact field current required to produce constant voltage. The impedance of the saturable reactor is controlled by the two d.c. exciting coils, B and C. Under

automatically control the field current of the a.c. generator to maintain a constant line voltage in the output circuit of the a.c. generator. It consists principally of a number of reactors, transformers, and rectifiers. A schematic diagram of this regulator is shown in Figure 9-3. For simplification the relays and controls are not shown.

When the voltage regulator is not energized, the a.c. voltage can be controlled manually by the generator field rheostat. To put the regulator in operation, the voltage regulator switch is closed. This supplies power to the main power transformer and, through relays, transfers generator field control to the voltage regulator.

The main rectifier, No. 1, is supplied from the winding A on the main power transformer, and from the current transformer. The reactor L_2 is connected across the current transformer so that the voltage supplied by this unit will have proper phase relationship to the voltage supplied by the main power transformer. This phase relationship is such that the vector sum of the voltages across the two units is approximately proportional to the field current required by the generator to maintain constant voltage, regardless of power factor.

The saturable reactor L_3 is connected in series with the main rectifier supply, and its impedance is automatically adjusted to maintain normal operation, the magnetizing forces provided by these two coils are approximately equal but in opposite directions. The current in coil C, which tends to saturate the reactor, is supplied by transformer No. 3 and rectifier No. 3, and is proportional to the output voltage of the generator. The current in coil B tends to reduce the saturation of the reactor and is supplied by rectifier No. 2. The power for this rectifier is supplied by the main power transformer windings and is controlled by the saturated reactor L_1 and the voltage control.

Since reactor L_1 is saturated, a small change in the voltage supplied to the circuit causes a relatively large change in the current flowing through the rectifier and through the reactor coil B. By adjusting the voltage control and the tap on the main power transformer winding, the ratio between the load voltage and the voltage supplied to the reactor L_1 can be varied.

Coil B is used to control the degree of saturation in the reactor L_3. Coil C is used to provide a base magnetizing force so that the total magnetizing force will be extremely low. This is done because reactor L_3 is most sensitive to a change in magnetizing force when the total magnetizing force is nearly zero.

In operation, the voltage control is set so that the load voltage is of the desired magnitude. If the load voltage becomes momentarily too large, the current through reactor L_1 is

increased greatly, and the d.c. winding B reduces the saturation of the saturable reactor. This increases its impedance and thus reduces the field current supplied to the generator, returning the load voltage to its normal value. If the load voltage becomes momentarily too low, the current in reactor L_1 decreases greatly, and the load voltage is brought up to its normal value in a similar manner.

When a load is applied to the generator, the increased current in the current transformer supplies a greater voltage to rectifier No. 1, thus instantly increasing the field voltage to the value required to maintain constant load voltage. When the load is decreased, the opposite occurs. To clarify the operating principle of the saturable reactor, Figure 9-4 shows rectifiers No. 2 and No. 3 of Figure 9-3 replaced by batteries. Coil C of the saturable reactor receives a constant potential from one of the batteries while a rheostat inserted in the battery circuit supplying coil B permits voltage to that coil to be varied. Variation of the voltage in coil B controls the impedance of the saturable reactor and this in turn regulates the generator field through the main rectifier. The rheostat in the circuit of coil B takes the place of the saturable reactor L_1 and the voltage control shown in Figure 9-3.

9C2. Operation. The operating procedure for this voltage regulator is the same as that given for the rotary solenoid type described in Section 9B2.

9C3. Maintenance. The only parts of this regulator that require maintenance are the relays, which are located on the control panel. Contact burning is kept at a minimum by having the relays electrically interlocked to prevent arcing. The contacts are of pure silver and are not affected by blackening. However, if the points become badly pitted, they should be dressed with a fine point file or replaced. The contact gap should be set between 1/8-in. and 3/16-in. The relay bearings should be kept free from dirt to insure satisfactory operation.

The manufacturer's instructions should be studied and followed in replacing or adjusting any parts of the regulator that may require such service.

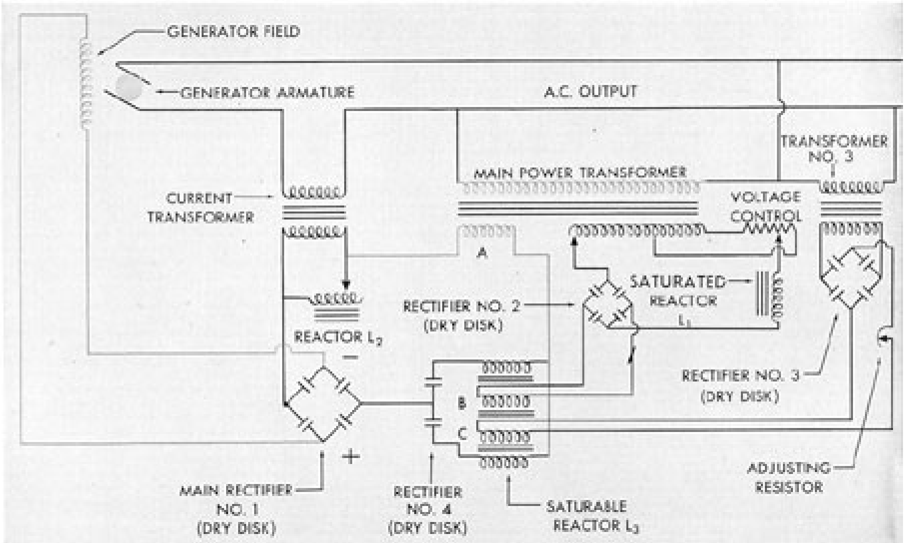

Figure 9-3. Schematic diagram of I.C. motor generator voltage regulator, reactor type.

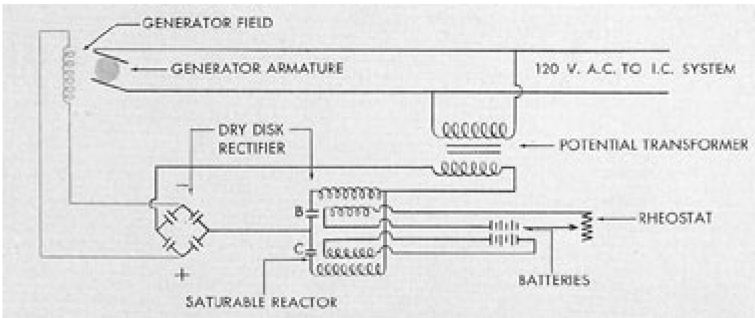

Figure 9-4. Equivalent schematic diagram of I.C. motor generator voltage regulator, reactor type.

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10
SELF-SYNCHRONOUS TRANSMITTERS AND INDICATORS

A. DESCRIPTION

10A1. General description. Self-synchronous transmitters and indicator units are used in the following I.C. systems:

Motor order telegraph system

Rudder angle indicator system

Bow and stern plane angle indicating systems

Underwater log system

Shaft revolution indicator system

Gyrocompass repeater system

Various fire control systems

Self-synchronous units are manufactured by various companies which refer to them by trade names such as Selsyns, Synchros, Auto syns, and Telmotors. The theory of operation is the same for all the various types of units. For brevity, they will be referred to as selsyns in the following text.

Thee are 2 basic designs of selsyn units, One employs a 3-phase motor and a single phase stator, the other employs a single-phase rotor and a 3-phase stator. Both are energized by 115 volts, 60 cycle, single-phase, alternating current. They will operate efficiently on a voltage and frequency variation of +- 10 percent. That is, they will operate in a voltage range of 103.5 volts to 126.5 volts and a frequency range of 54 cycles to 66 cycles. The 3-phase rotor, single-phase stator design is most commonly used in submarine equipment.

The indicators (motors) differ only mechanically from the generators (transmitters) in that a mechanism for dampening oscillations is mounted on the rotor shaft. Electrically, they are identical.

The type designations that the Navy uses for selsyn units indicate principally the size of the unit. Common types used in submarines are:

Types "A" and "B" transmitters (generators). Type "B" is larger than type "A."

Types "N" and "M" indicators (motors). Type "N" is larger than type "M."

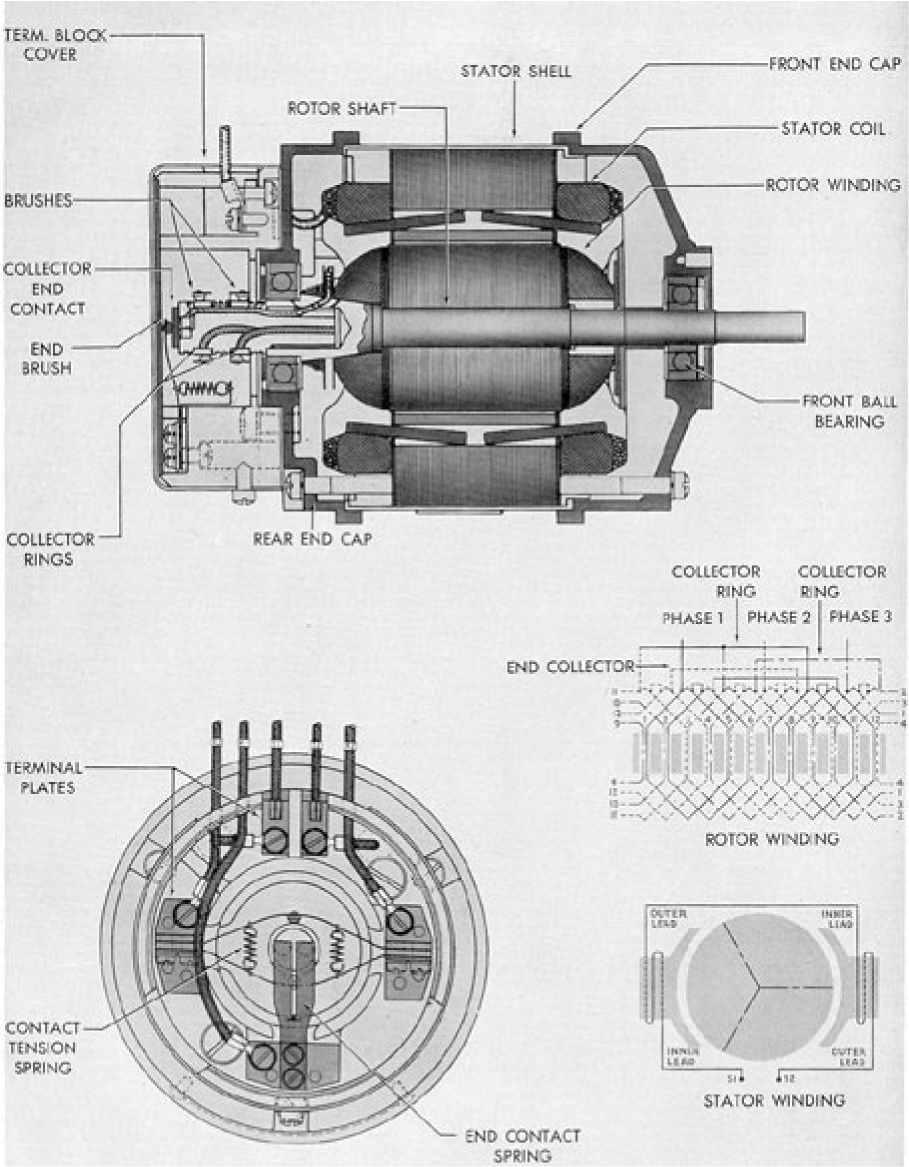

Figure 10-1. Sectional view of type "A" transmitter.

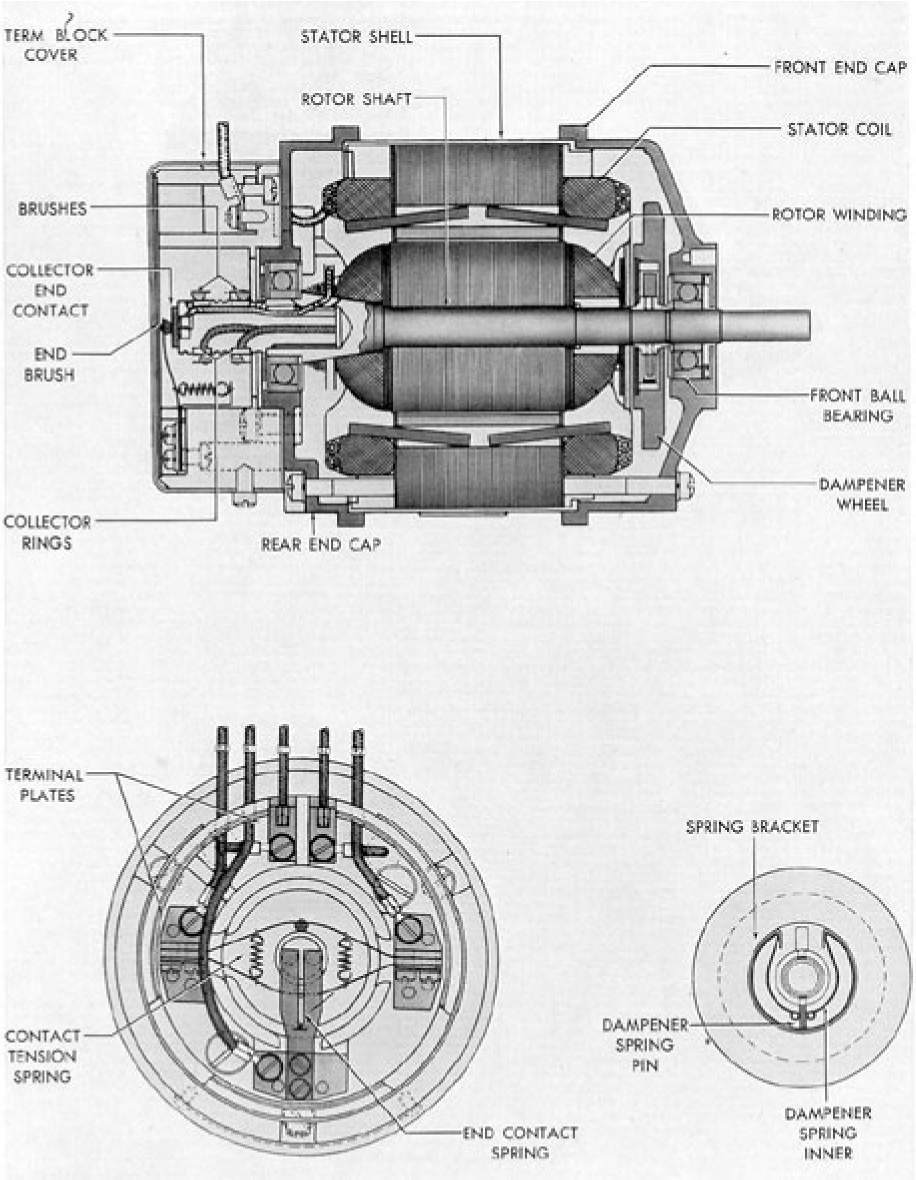

Figure 10-2. Sectional view of type "M" indicator.

B. OPERATION

10B1. Principle of operation. The following discussion is based on the 3-phase rotor, single-phase stator design (Figure 10-4).

The stator or fields of the transmitter and all indicators in the circuit are connected to the same supply. The 3-phase rotors are connected electrically. When the supply circuit is closed, a single-phase alternating current is impressed on the circuits, setting up a torque. If the indicator rotor is free to turn, the reaction is a restoring of the original balance which results in the indicator rotor being, brought into agreement with the transmitter rotor.

10B2. Maintenance. a. General. The brushes and slip rings should be cleaned periodically with an approved solvent. Even though the silver slip rings and contacts may become discolored, the

interconnected stators. The single-phase current in the stator windings, or primary circuits, induces voltages in the rotor windings, or secondary circuits. If the indicator rotors are in exact correspondence with the transmitter rotor, the voltage in phase 1 (R_1) of the indicators is equal to the voltage in phase 1 of the transmitter. The same condition applies to phases 2 and 3 (R_2 and R_3). Because these voltages are balanced, no current will flow in these circuits. If the transmitter rotor is moved, the balance is destroyed. Currents then flow in the rotor conductivity is not necessarily reduced. The ball bearings should be lubricated periodically with a small amount of light mineral oil. Sticky bearings, which may cause the indicators to move sluggishly or prevent them from following the transmitter accurately, should be repaired at once or the unit will burn out. The greater the displacement between transmitters and indicators, the greater the current flow. The dampener mechanism of the indicators should be inspected periodically to insure that its

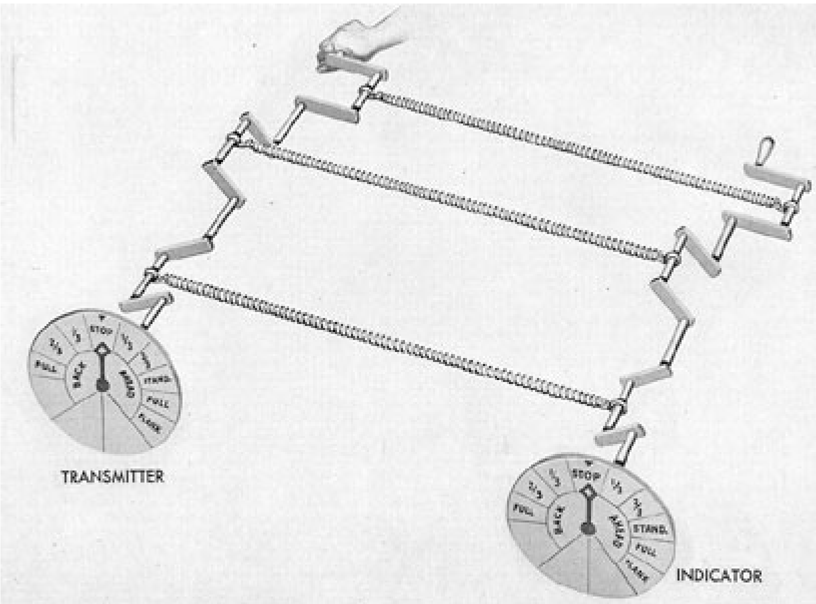

Figure 10-3. Mechanical analogy of selsyn transmitter and indicator.

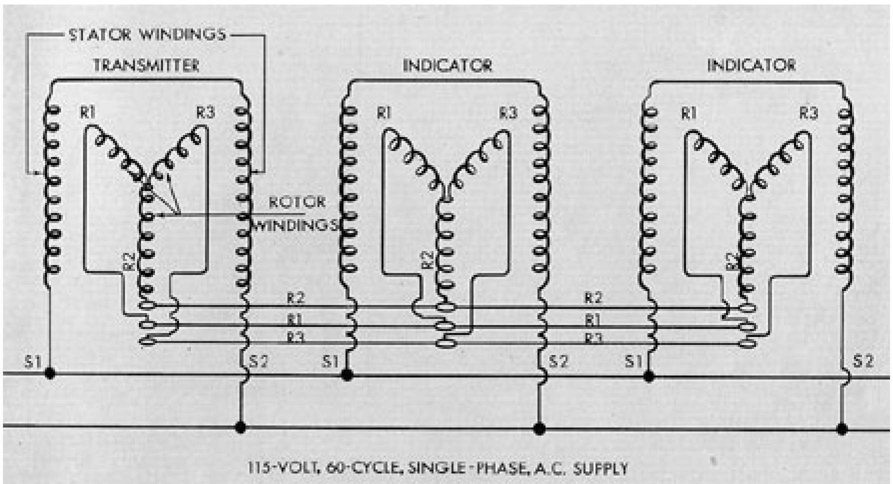

Figure 10-4. Elementary wiring diagram of selsyn transmitter and indicators.

action is not sluggish. All connections should be kept tight and the circuits kept clear of grounds. Should it become necessary to replace a unit, care must be taken to insure that all electrical circuits are connected in their proper relation. The following procedure will insure proper performance of instruments at all times:

1. If trouble develops in a system, always check the fuses and external wiring first. Inspect for short circuits, grounds, or opens before tampering with the instruments or selsyn units.

2. Check selsyn units for erratic or sticky operation.

3. See that all gears are tight on their shafts, and also that they are meshing properly.

4. Examine all bearings for dirt and free operation. Clean, and then lubricate them with a drop of fine, light oil.

5. Check the multipronged plug, jackboard, and the terminal bar solder connections for continuity.

6. Instruments that must be opened to replace lamps or for other purposes should not be left open any longer than necessary. Take care that the ring light surfaces are not scratched. When replacing covers, make certain that the handle and rheostat shafts are properly aligned. The drain valve, which is at the lowest point of the instrument case, can be opened to remove moisture which may have condensed in the instrument. Opening of this drain valve will also equalize pressures during compartment air tests.

7. To replace self-synchronous motive power units, it is necessary to remove the entire interior mechanism and the jackboard internal wiring to the selsyn units.

CAUTION. When replacing a selsyn unit, the electrical zero marks on the unit must be aligned with the zero marks on the mounting plate and gears. (See Section 10B2c.)

b. Trouble indications. On page 137 is a table of conditions that may be encountered in the operation of selsyn units due to circuit derangements and mechanical troubles.

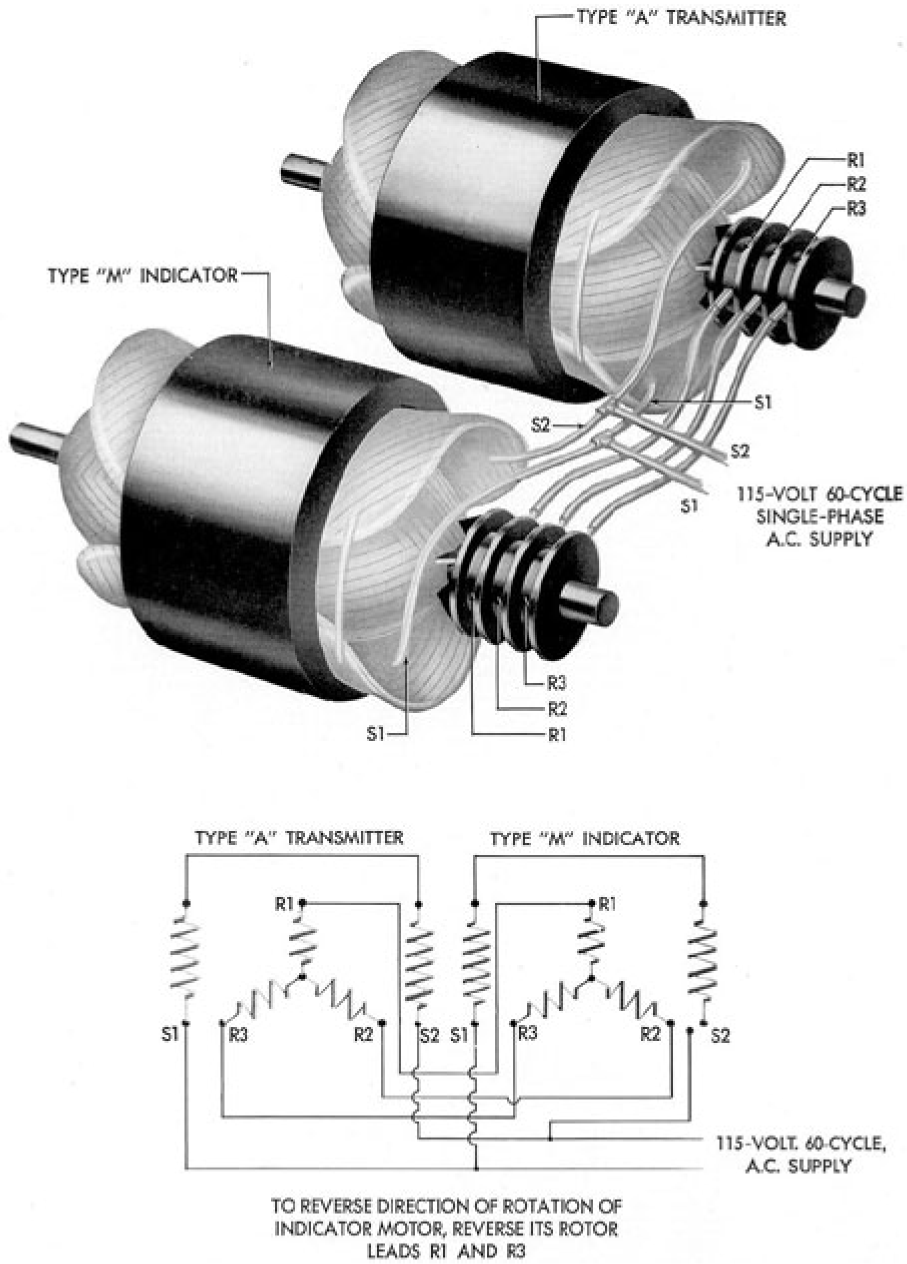

Figure 10-5. Elementary wiring diagram showing connections between selsyn transmitter and indicator.

Trouble Indications	Causes
Indicator pointers are 180 degrees out of position with the transmitter pointer.	Reversed stator leads.
Indicators follow accurately as long as transmitter is moved along slowly. If transmitter is moved rapidly, indicators get out of position.	Open stator lead.
Indicator moves erratically over dial.	Open rotor lead.
Indicator is 120 degrees out to the	Reversed R_1 - R_2

5. Loosen the setscrew that holds the arrow in position on the arrow collar and loosen the screws that hold the clamping collar.

6. Move the arrow to the center of the STOP position on the dial. Tighten the screws in the clamping collar, then tighten the setscrew that secures the arrow to the collar.

7. Replace the original external wires. The unit should now

right and rotates opposite to transmitter.	
Indicator rotates opposite to transmitter rotation.	Reversed R_1 - R_3
Indicator oscillates back and forth before coming to rest.	Sticky damper.
Indicator does not follow accurately and has a pronounced hum	Sticky bearings, bent shaft, or other misalignment.
Rotor operates as an induction motor	The three rotor leads are shorted or connected together. Such a condition will quickly burn out the rotor winding.

c. Electrical zero setting. When a transmitter or an indicator is removed from an instrument and replaced, it is necessary to reset the arrow. The instructions given here assume that circuit MB is being set. The procedure is as follows:

1. Check to see that the transmitter arrow is at the center of the STOP position.

2. Install the new unit in position mechanically.

3. Cross connect S_1 with R_2 and S_2 with R_1 and R_3 (see Figure 10-6).

4. Connect 115-volt, 60-cycle, single-phase, alternating current to leads marked MB and MBB. The rotor will now assume its electrical zero position.

synchronize with the other units in the system.

NOTE. The electrical zero setting for instruments used in angle indicating systems should be made to center the indicating arrow on the 0 or zero position.

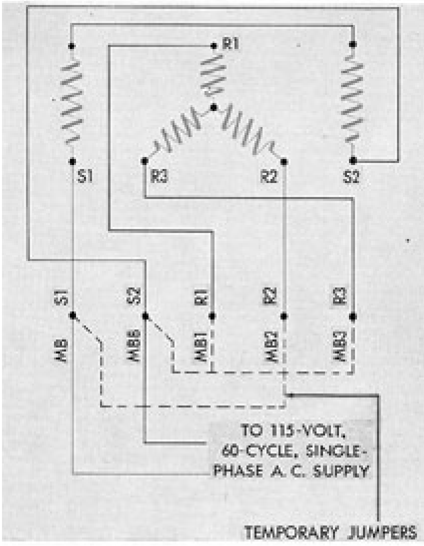

Figure 10-6. Selsyn connections for electrical zero.

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11
SELSYN-OPERATED SYSTEMS

A. MOTOR ORDER TELEGRAPH SYSTEM

11A1. Description. The motor order telegraph system consists of 2 separate electrical circuits. The starboard circuit is designated 1MB and the port circuit, 2MB. Electrically both circuits are identical. The system is operated on 115-volt, 60-cycle, single-phase, alternating current. Each circuit receives its supply from the a.c. bus of the I.C. switchboard through fused switches.

The purpose of the motor order telegraph system is to transmit electrically any desired orders for the direction and speed of the propellers from the transmitting stations located in the conning tower and control room to the maneuvering room and to repeat those orders back to the transmitting station from the maneuvering room.

The circuits are controlled through rotary switches on the action cutout switchboard. One switch selects the conning tower or the control room as the transmitting station for both 1MB and 2MB circuits. Two more switches select either the conning tower, control room, or both, as the receiving station for the repeat back orders from the maneuvering room. One of these station. The bell signal rings whenever the transmitter is being moved from one position to another. Auxiliary contacts for the bell signal are operated by a push button on the cover of the instrument. They are connected in parallel with the contacts operated by the star wheel. The auxiliary bell-ringing circuit is energized at any time the push button is operated. The indicator pointer is connected directly to the rotor of the indicator through an extension shaft.

The maneuvering room instruments are similar except for an additional mechanism consisting of a cam mounted on the transmitter shaft which operates a contact for wrong direction warning. These contacts are connected with contacts on the reverser levers of the main control cubicle. If the reverser levers are moved in a direction opposite to that indicated by the transmitter pointers of the maneuvering room instruments, a visual and audible signal informs the operator of the error.

11A2. Operation. In order to energize the system, the- IMB and 2MB circuit switches on the I.C. switchboard must be turned to the ON position. On the action cutout switchboard, turn the 1MB-2MB

2 switches is for the 1 MB, the other for the 2 MB indicators.

The conning tower and control room units consist essentially of a type "A" transmitter and pointer, a type "M" indicator and pointer, 2 sets of contacts for bell-ringing circuits, and necessary operating gears. The assembly is mounted in a case.

The transmitter is operated by a knob type handle fastened to a shaft on the front cover of the instrument. This shaft is connected to the transmitter rotor by means of a positive engaging clutch. A star wheel mounted on the transmitter shaft holds the transmitter in the desired position by means of a spring loaded main bell contact actuating lever. This lever also operates the contacts for the bell signal at the indicator

transmitter selector switch to the station that is to control transmission. This switch is marked CONNING TOWER, OFF, and CONTROL ROOM. Next, turn the 1MB and the 2MB indicator selector switches to those stations that are to receive a repeat indication of the transmitter order. These switches are marked CONNING TOWER, OFF, CONTROL ROOM, and CONTROL ROOM AND CONNING TOWER.

NOTE. Before transferring control from one station to another, be sure that the station you are transferring to has its transmitters set on the same order, otherwise, the maneuvering room will receive whatever order is indicated at the new transmitting station.

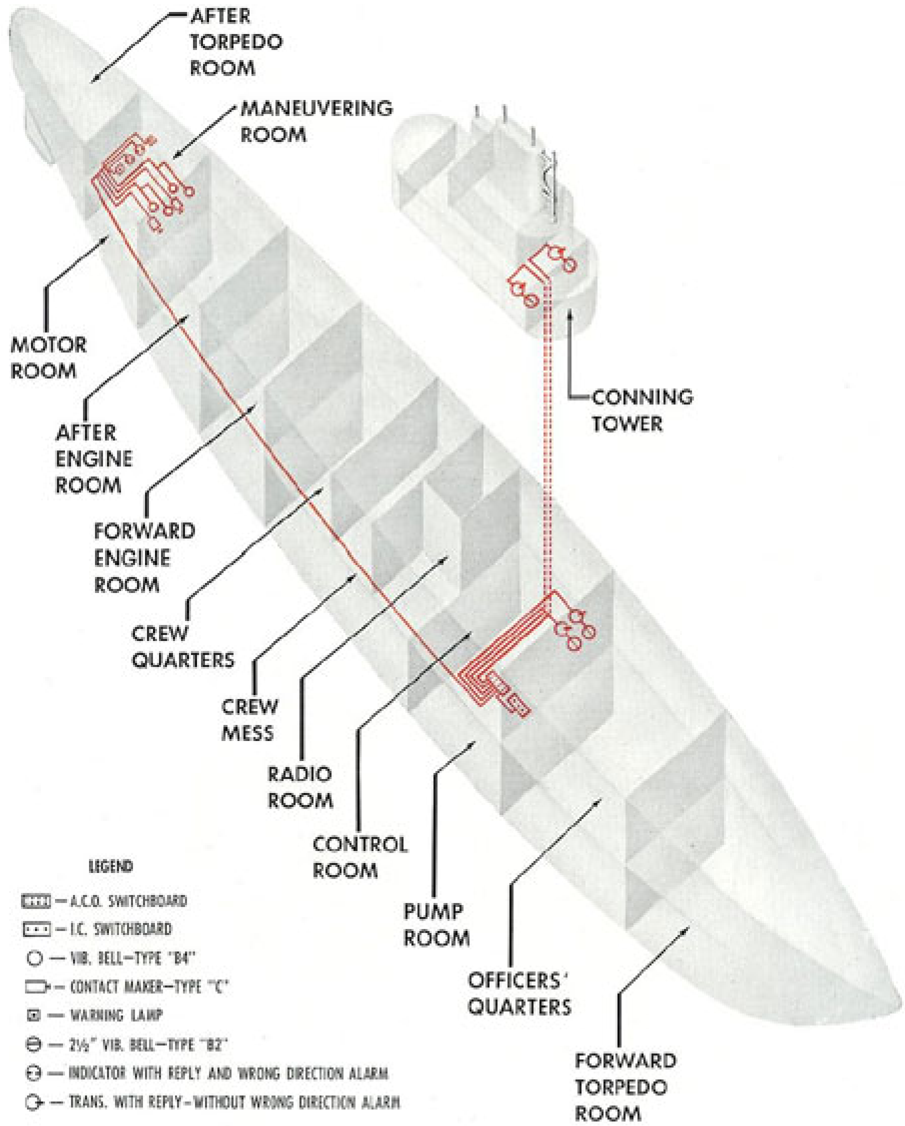

Figure 11-1. Schematic diagram of motor order telegraph system.

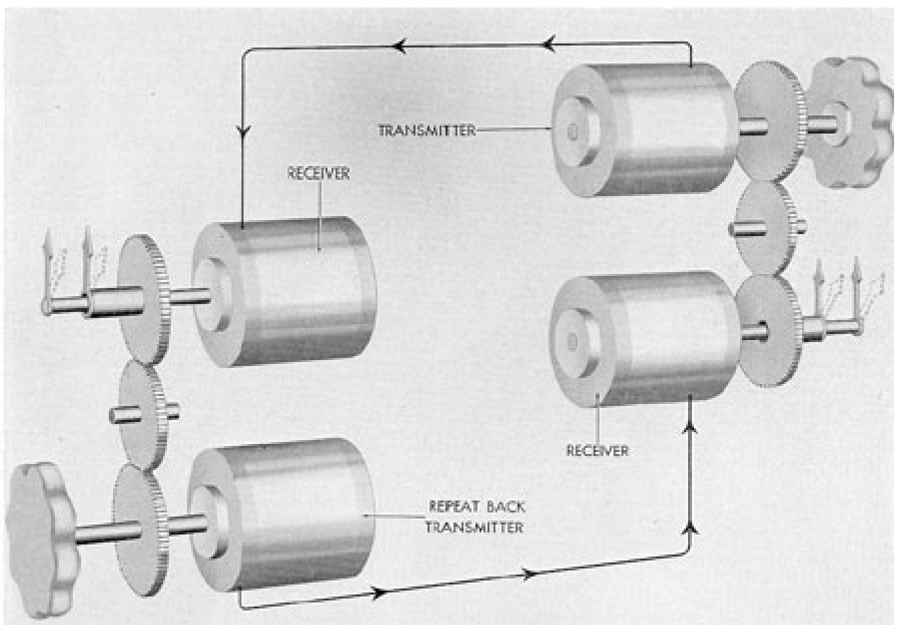

Figure 11-2. Schematic diagram of motor order telegraph, two units.

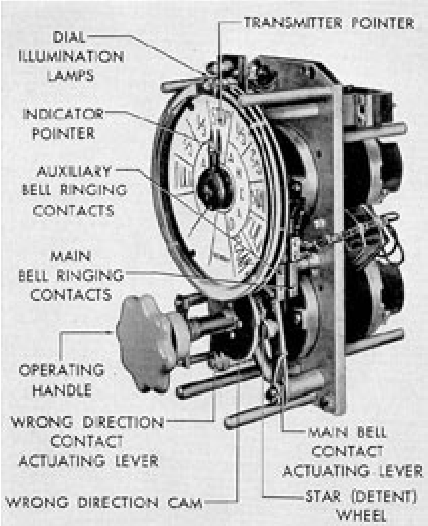

Figure 11-3. Motor order telegraph transmitter indicator unit, maneuvering room.

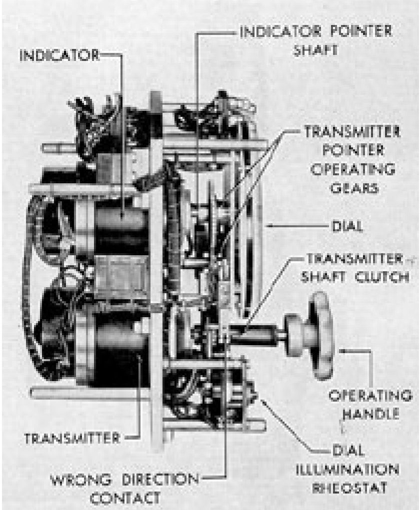

Figure 11-4. Side view of motor order telegraph transmitter indicator unit, maneuvering room.

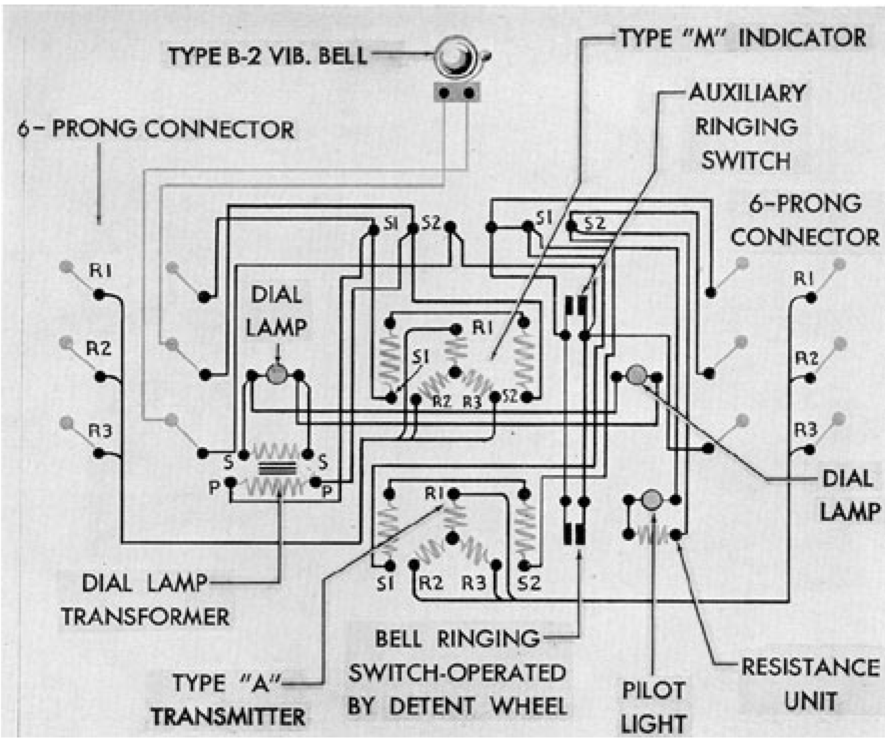

Figure 11-5. Elementary wiring diagram of motor order telegraph transmitter indicator, conning tower and control room units.

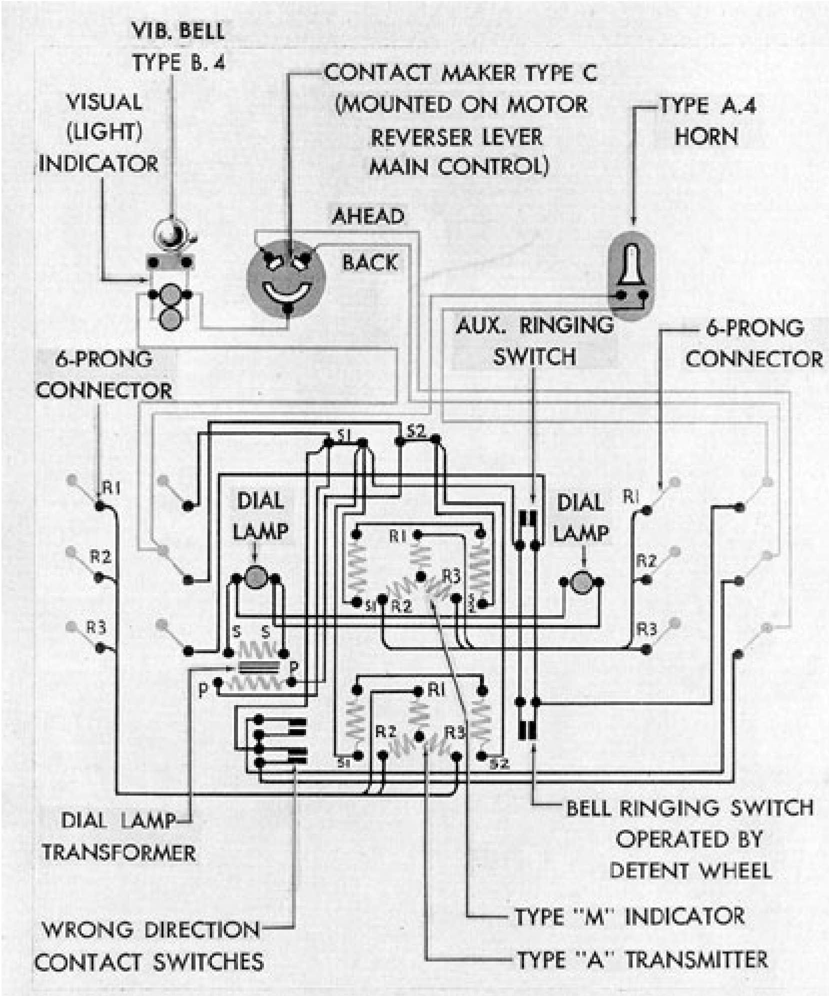

Figure 11-6. Elementary wiring diagram of motor order telegraph transmitter indicator, maneuvering room unit.

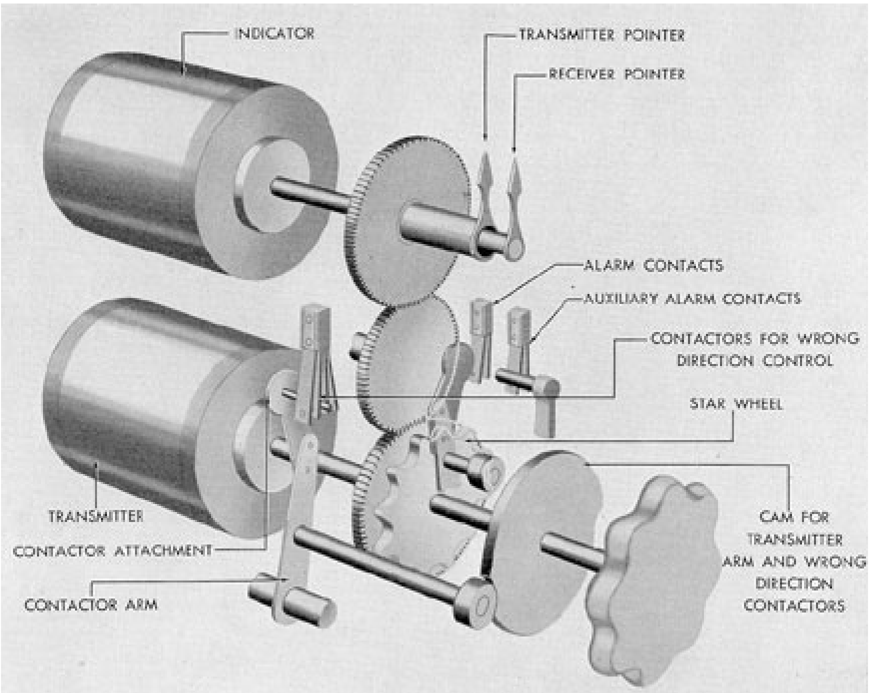

Figure 11-7. Schematic diagram of motor order telegraph transmitter and indicator.

11A3. Maintenance. The bearings, gears, cams, and other pressure test is to be conducted in a compartment in which an

moving parts should be inspected periodically to see that they are in proper alignment and working freely. A drop or two of fine-grade mineral oil may be applied to the bearings if necessary. Contacts should be checked for signs of pitting and wear. Slightly worn or pitted contacts may be dressed with very fine sandpaper and crocus cloth.

The instrument cases are sealed. If a instrument is located, make certain that the plug located on the case is opened. With the plug opened, the air pressure in the compartment necessary to conduct the test, and the pressure in the case will be equalized, thus avoiding possible damage to the instrument.

The transmitters and indicators should be maintained as outlined in the maintenance instructions for selsyn units (Section 10B2).

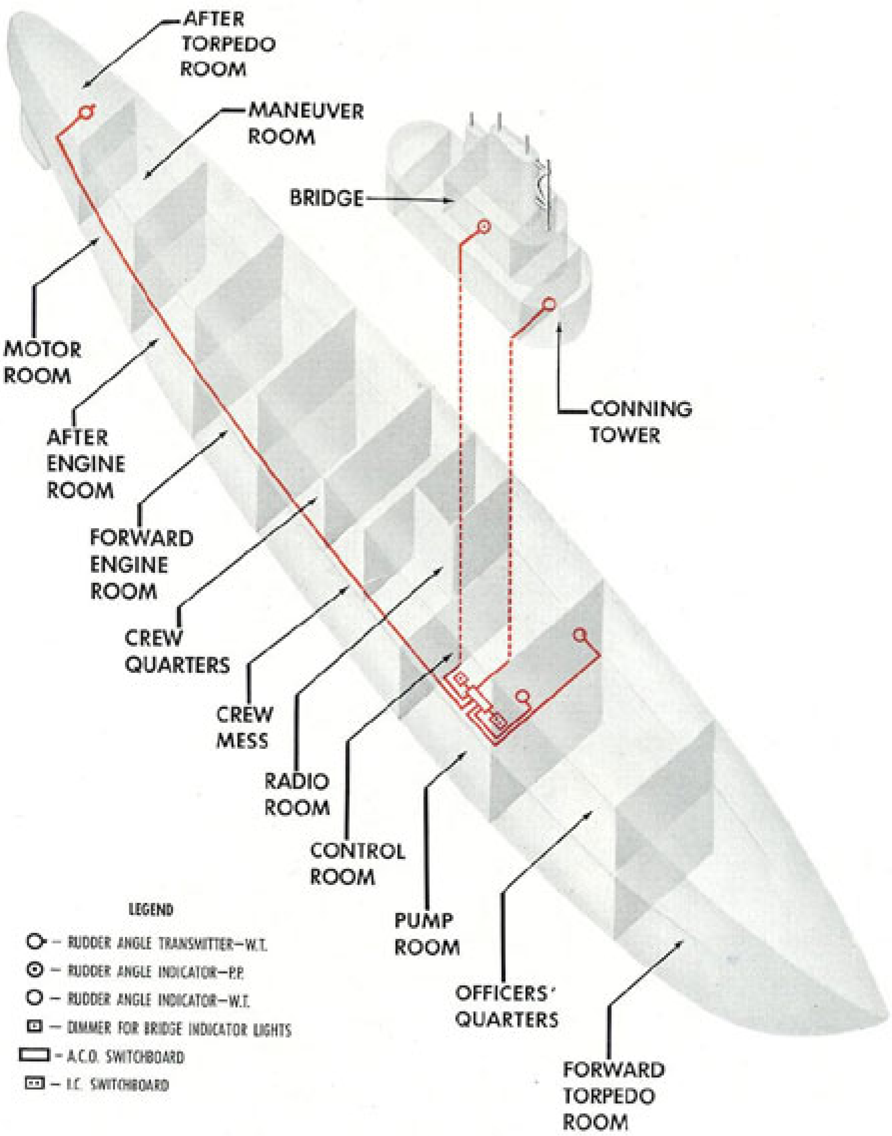

Figure 11-8. Schematic diagram of rudder angle indicator system.

B. RUDDER ANGLE INDICATOR SYSTEM

11B1. Description. The rudder angle indicator system is designated as circuit N. It is operated on 115-volt, 60-cycle, single-phase, alternating current and receives its supply from the a.c. bus of the I.C. switchboard through a fused switch.

The purpose of the system is to transmit electrically the angular position of the rudder to various stations in the control room, conning tower, and bridge.

The circuit is controlled through 2 rotary contact switches on the action cutout switchboard. One switch energizes the conning tower and bridge indicators, the other switch energizes

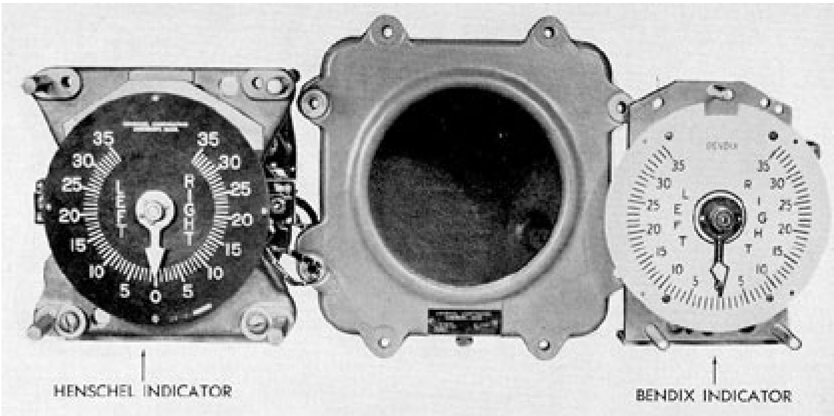

Figure 11-9. Rudder angle indicator and case.

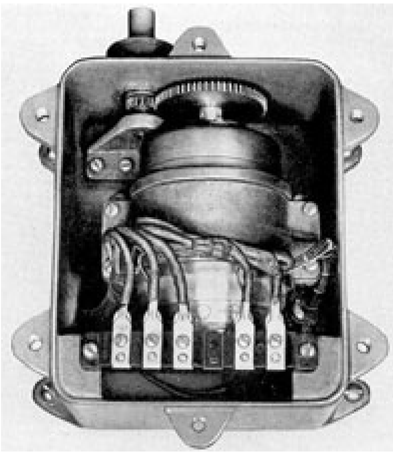
Figure 11-10. Rudder angle transmitter.

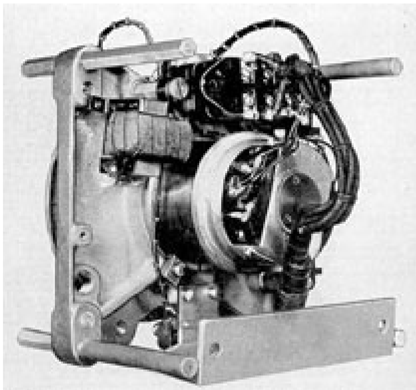
Figure 11-11. Rear view of rudder angle transmitter.

the indicators located in the control room.

The transmitting instrument consists essentially of a type "A" transmitter mounted in a case. Any movement of the rudder is transmitted mechanically those stations at which an indication of the rudder angle is desired. One of these switches controls the bridge and conning tower indicators. It is marked BRIDGE, OFF, CONNING TOWER, and BRIDGE AND CONNING

through a linkage or gear arrangement that causes the rotor of the type "A" transmitter to rotate in a corresponding direction.

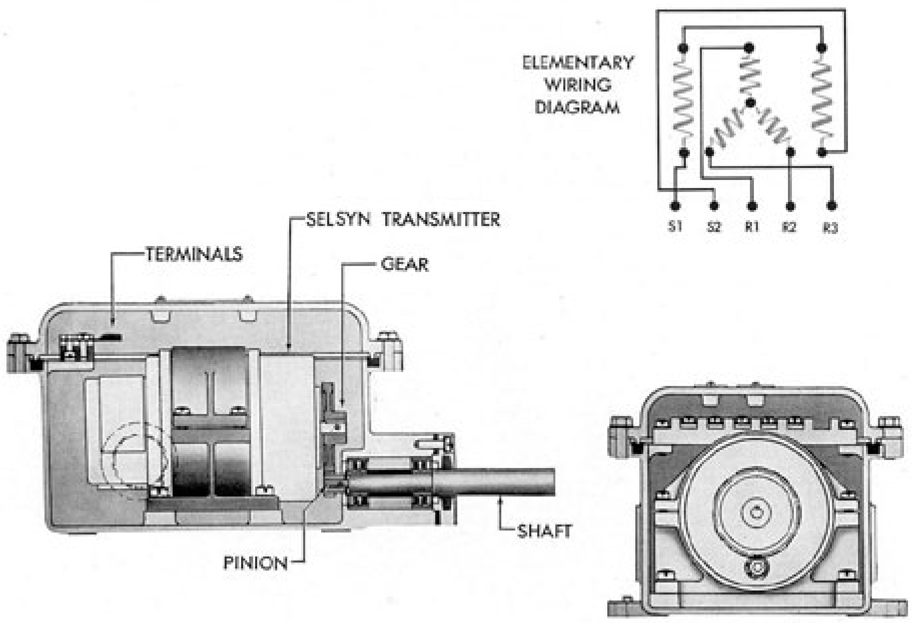

Figure 11-12. Cross-sectional view of rudder angle transmitter.

The indicating instrument consists essentially of a type "M" indicator, a pointer, and a dial mounted in a case. The indicator pointer is secured to the indicator rotor shaft.

11B2. Operation. In order to energize the system, the circuit N switch on the I.C. switchboard must be turned to the ON position. On the action cutout switchboard, the circuit N indicator selector switches should be turned to TOWER. The other switch controls the control room indicators and is marked STEERING STATION, OFF, DIVING STATION, and DIVING AND STEERING STATION.

11B3. Maintenance. The operating mechanism between the transmitter instrument and the rudder should be examined periodically to make certain that it is operating freely but without any backlash. For maintenance of the selsyn units, the procedure outlined in Section 10B2 should be followed.

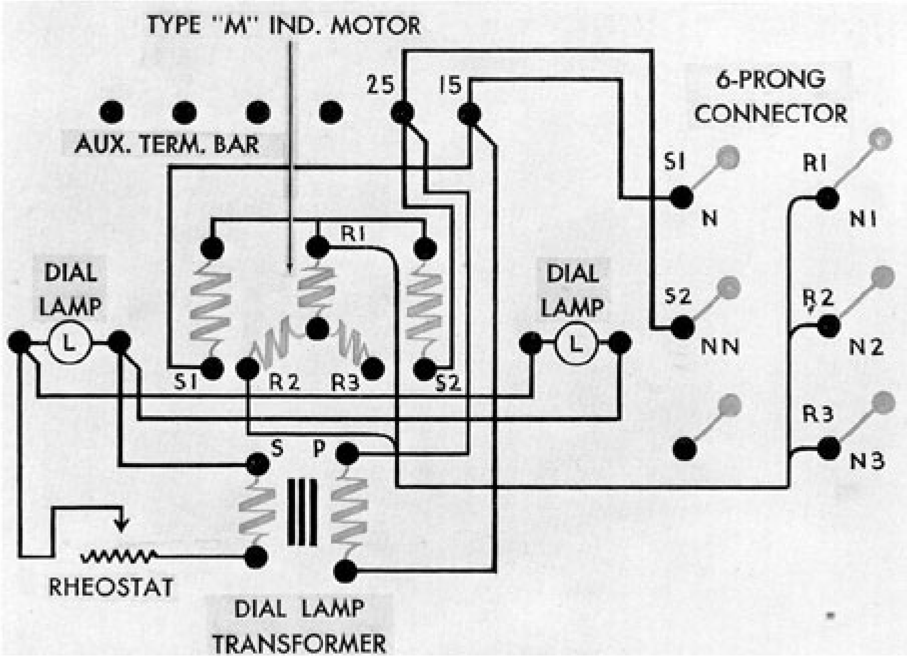

Figure 11-13. Wiring diagram of rudder angle Indicator.

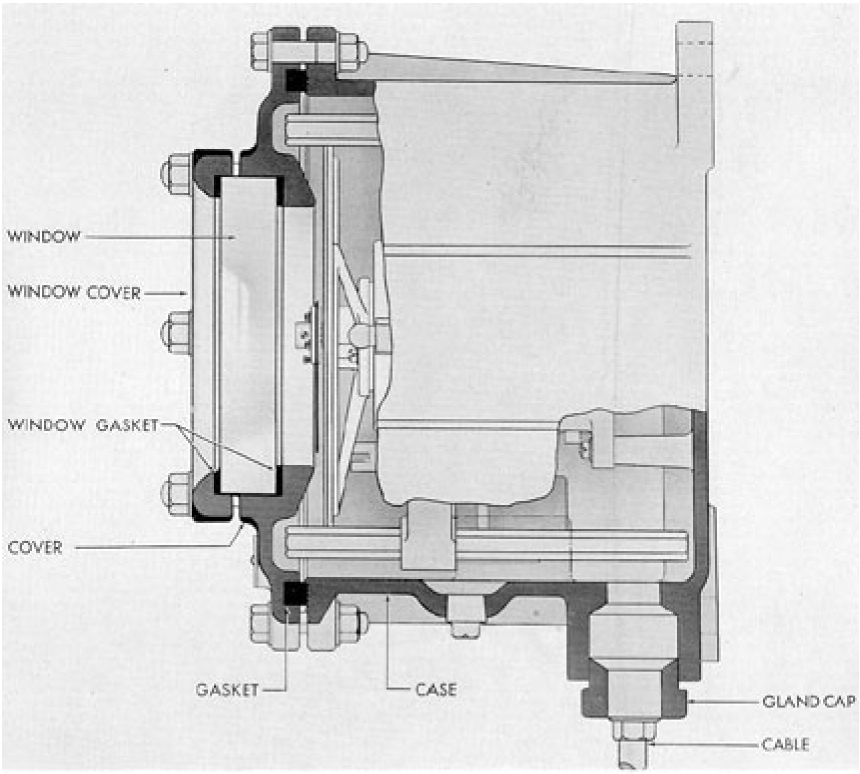

Figure 11-14. Rudder angle Indicator, showing pressure-proof construction for bridge installation.

C. BOW AND STERN PLANE ANGLE INDICATING SYSTEMS

11C1. Description. The bow plane angle indicating system is designated as circuit NB. The stern plane angle indicating system is designated as circuit NS. Both of the systems are XNS (stern plane) are provided for use in the event of failure of the selsyn-operated systems (see Section 11C4).

operated on 115-volt, 60-cycle, single-phase, alternating current, and receive their supply from the a.c. bus of the I.C. switchboard individually, through fused switches.

The purpose of the systems is to transmit electrically the angular position of the bow and stern diving planes to the diving station in the control room. The instruments and the mechanical arrangements connected to them are similar to those employed in the rudder angle indicator system.

Auxiliary circuits XNB (bow plane) and

11C2. Operation. The bow plane angle indicator system is energized by turning the switch labeled for this system on the I.C. switchboard to the ON position. The stern plane angle indicating system switch is also on the I.C. switchboard; turning it to the ON position energizes the system.

11C3. Maintenance. The mechanical operating mechanism between the transmitters and the diving planes should be examined periodically to see that proper alignment and free movement without backlash are maintained. See Section 10B2 for maintenance of selsyn units.

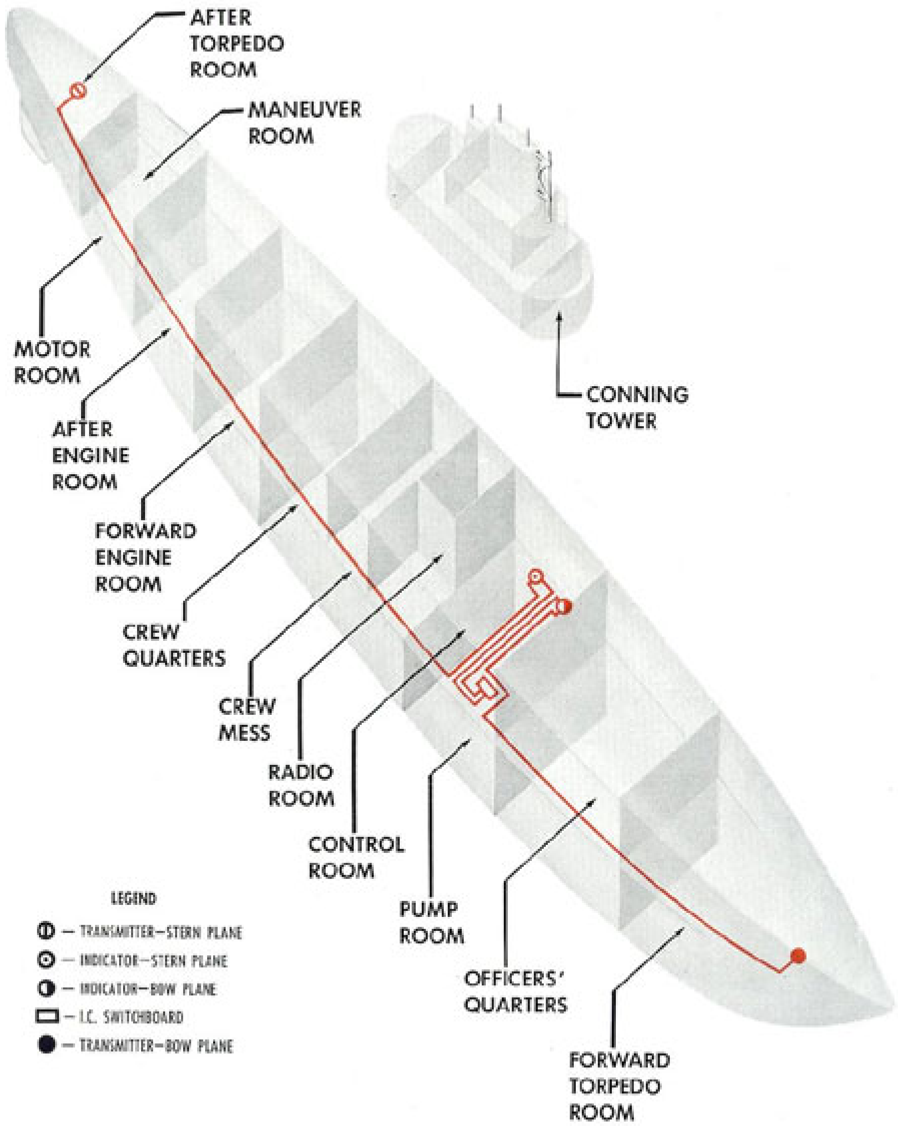

Figure 11-15. Schematic diagram of bow and stern plane angle indicating systems.

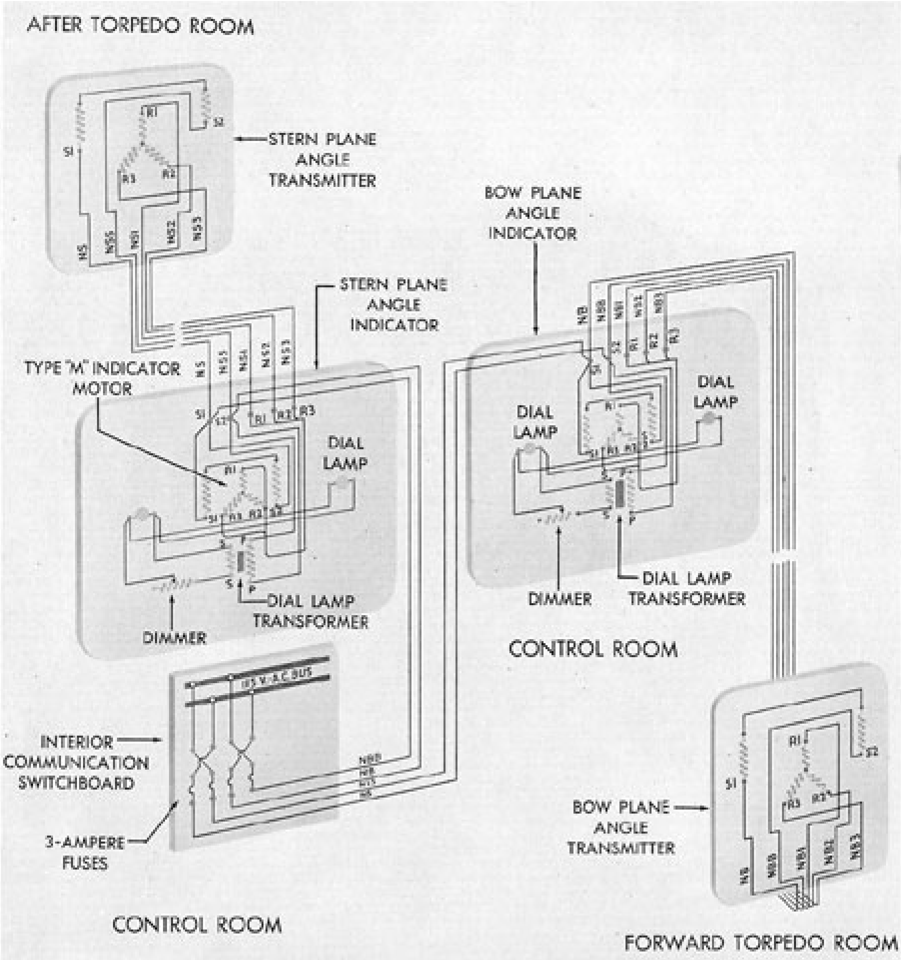

Figure 11-16. Wiring diagram of bow and stern plane angle indicating systems.

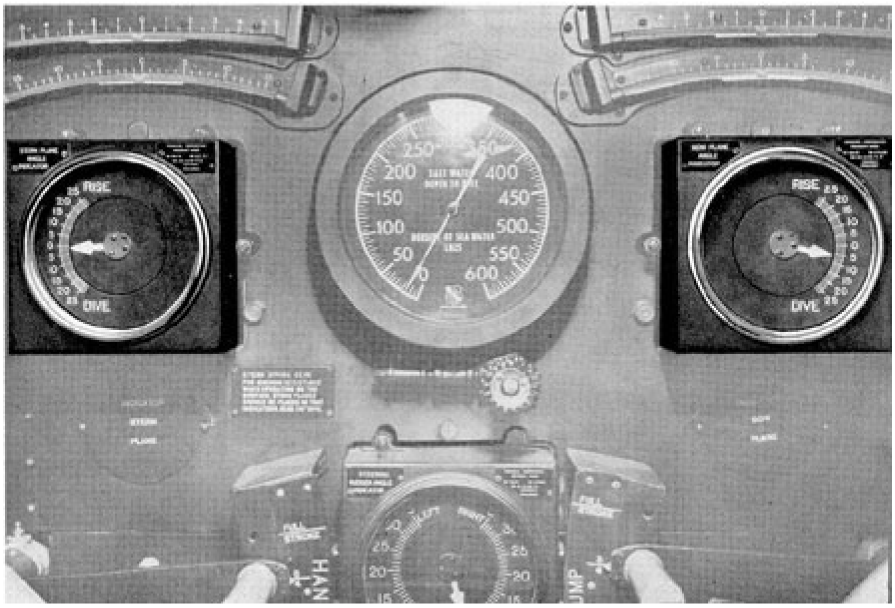

Figure 11-17. Bow and stern plane angle indicators installed at diving station.

11C4. Auxiliary bow and stern plane angle indicating systems. The auxiliary bow and stern plane angle indicating systems are provided for use in the event of failure of the regular selsyn- and lamp type indicators located in the control room.

Motion of the diving planes moves the mechanical transmitters across a number of contacts, thus closing

operated systems (Section 11C1) or of the I.C. power.

The circuits are designated XNB (bow plane) and XNS (stern plane) and consist of mechanical transmitters connected to the diving plane mechanisms, a group of dry cell batteries, the circuits to the lamps mounted on a panel in the control room. The dry cells are connected to produce an output of 6 volts for each of the circuits which are energized by means of a snap switch in the control room.

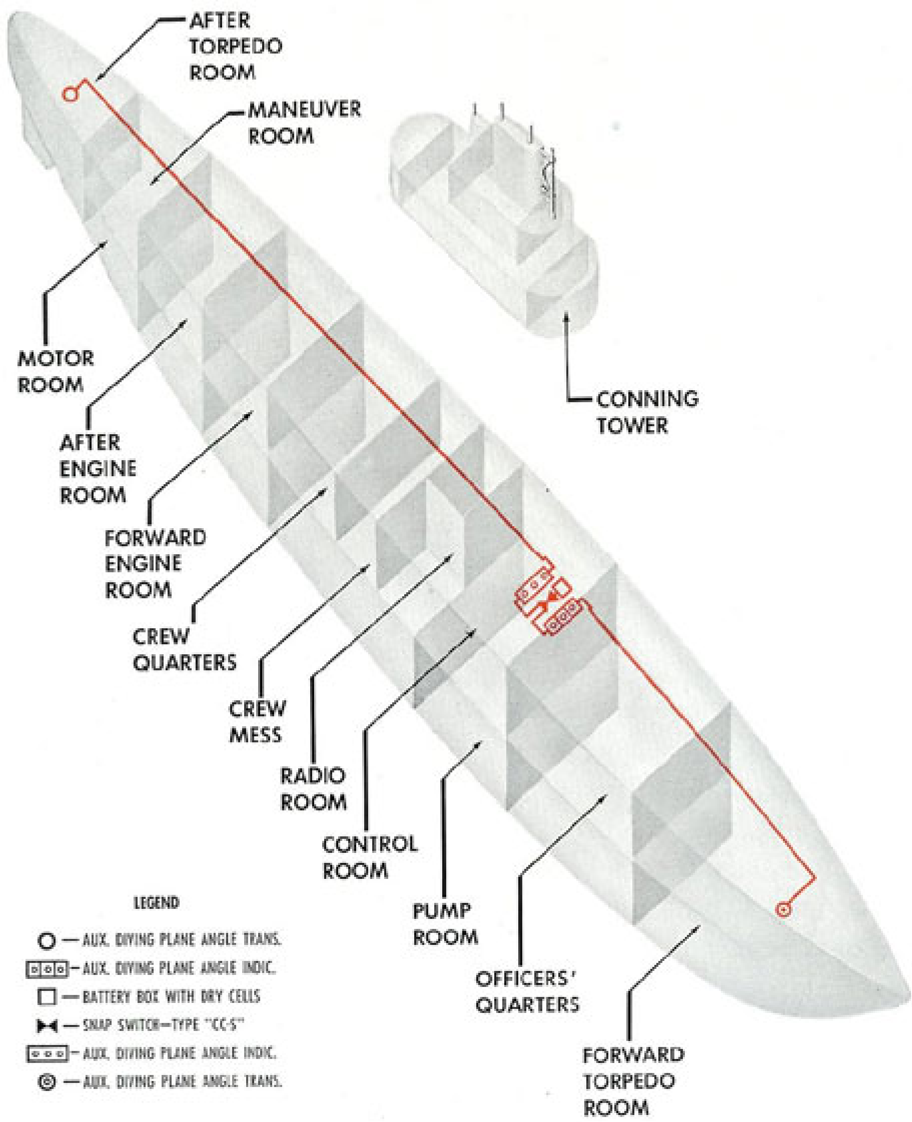

Figure 11-18. Schematic diagram of auxiliary haw and stern plane angle indicating systems.

CLUTCH IN RIG indicator at the diving station and closes a circuit to another contact maker on the windlass control valve in the forward torpedo room. This

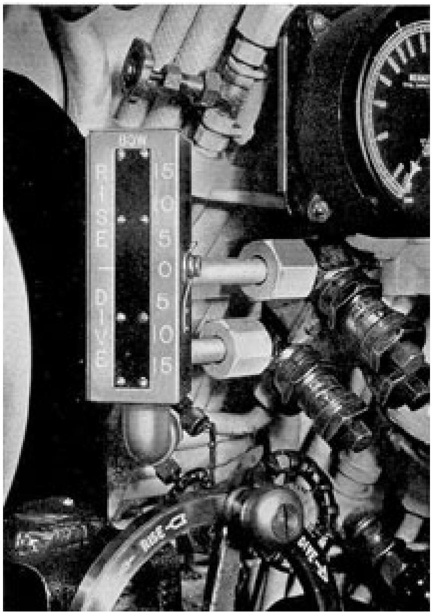

Figure 11-19. Auxiliary bow plane angle indicator at diving station.

11C5. Bow plane rigging electrical indicator system. The anchor windlass, bow capstan and bow plane rigging gear is electrically operated through hydraulic gearing and has an electric indicating system. The indicating system takes power at 120 volts d.c. through a snap switch and fuses on the I.C. switchboard in the control room, and shows indications at the diving station.

A contact maker on the rig windlass clutch in the forward torpedo room lights a contact maker is closed when the control valve is in neutral.

When both these contact makers are closed, the WINDLASS VALVE IN NEUTRAL indicator at the diving station is lighted and the circuit is completed to an interlock on the tilting gear which is closed only when the planes are at zero tilt.

When all three of these contact makers are closed, indicating that the clutch in the rig windlass control valve is in neutral and that the planes are at zero tilt, a PLANES AT ZERO indicator at the diving station is lighted. The circuit is then completed to a RIGGING LEVER RELEASE push button, also located at the diving station. Pressing this push button releases a solenoid latch on the rigging lever, allowing the planes to be rigged either in or out.

A traveling nut type limit switch on the rigging gear in the forward torpedo room closes a circuit at either end of its travel through the rig-windlass clutch and windlass control valve contact makers to PLANES OUT or PLANES IN indicators at the diving station.

An intermediate contact maker operated from the hydraulic interlock shaft of the rigging mechanism makes a series of intermittent contacts while the planes are rigging in or out and flashes an indicating light at the diving station to indicate that the planes are moving in or out. The circuit for this indicating light goes through the traveling nut limit switch so that the circuit is opened when the planes are full IN or full OUT.

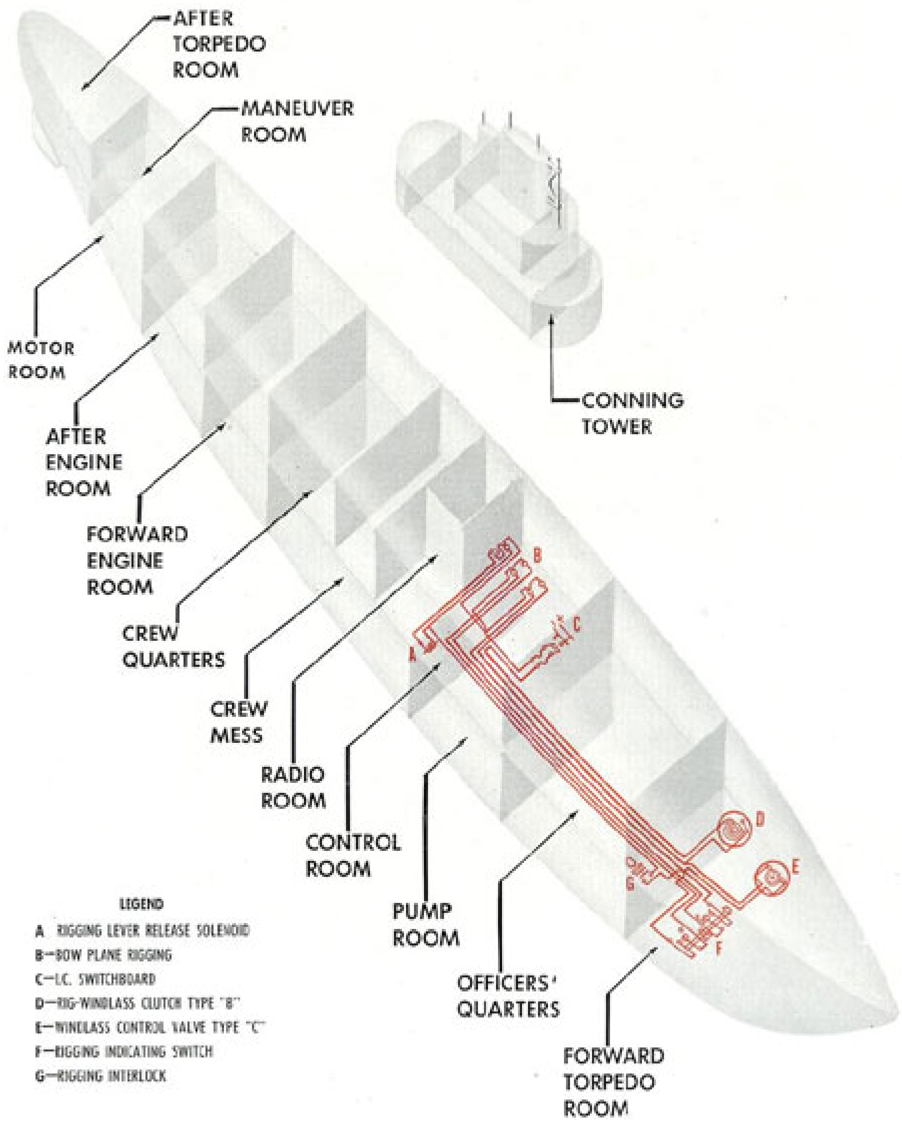

Figure 11-20. Schematic diagram of bow plane rigging indicator circuit.

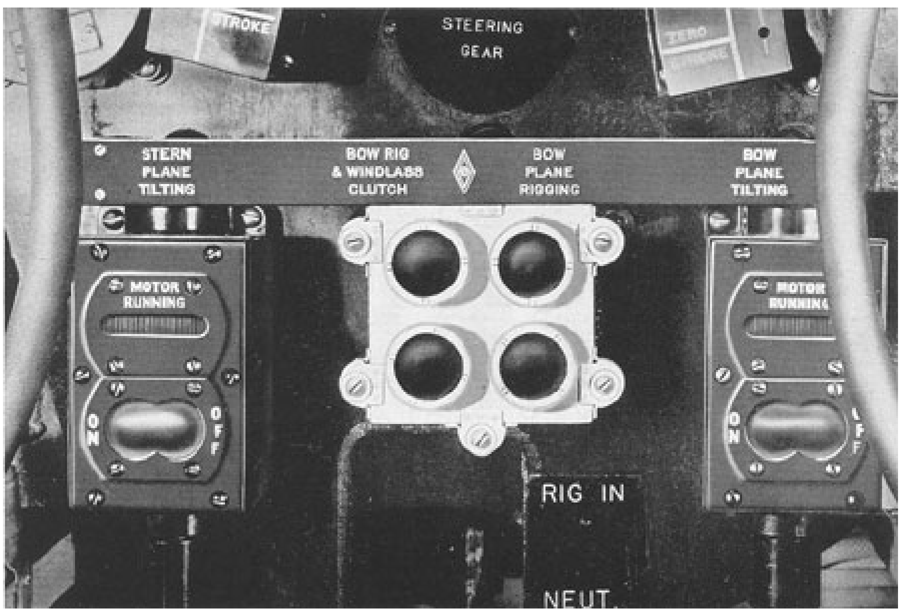

Figure 11-21. Bow plane rigging indicator, bow plane rigging and windlass

clutch indicator, bow and stern plane motor ON lights and controllers at diving station.

D. ENGINE GOVERNOR CONTROL SYSTEM

11D1. Description. a. General. The engine governor control system is the system through which the maneuvering room controls the speed of the engines. On vessels having single unit propulsion control cubicles, the system consists of 4 selsyn transmitters mounted in the governor control cabinet in the maneuvering room. Each transmitter is connected to a selsyn indicator (motor) mounted on the mechanical governor control of each engine. The indicators are geared to the rack shafts of the engine governors. When a change in the speed setting is made at the transmitters, the indicators move the rack shafts. They in turn transmit motion to mechanical linkage to establish an engine speed in accordance with the transmitter setting.

The system is designated as circuit EG and on earlier vessels is operated on 115-volt, 60-cycle, single-phase, alternating current supplied from the a.c. bus of the I.C. switchboard in the control room. On SS 313 and subsequent vessels, the governor control transmitters and receivers are of the direct current type described below and receive their power from the lighting system.

b. Engine governor control, direct current. The direct current position transmitters and receivers used in this type of governor control (Figure 11-23), while in external appearance similar to the a.c. types, are in reality entirely different both in principle of operation and in construction. The transmitter unit consists essentially of a continuous, cylindrical wire wound resistor unit. Two taps, diametrically opposite, are connected to slip rings which are fed through brushes from the 115-volt lighting circuit. Equally spaced around the fixed part of the transmitter shell are 4 more brushes which make contact directly on the wires of the resistor. The transmitter shaft turns the resistor unit mounted

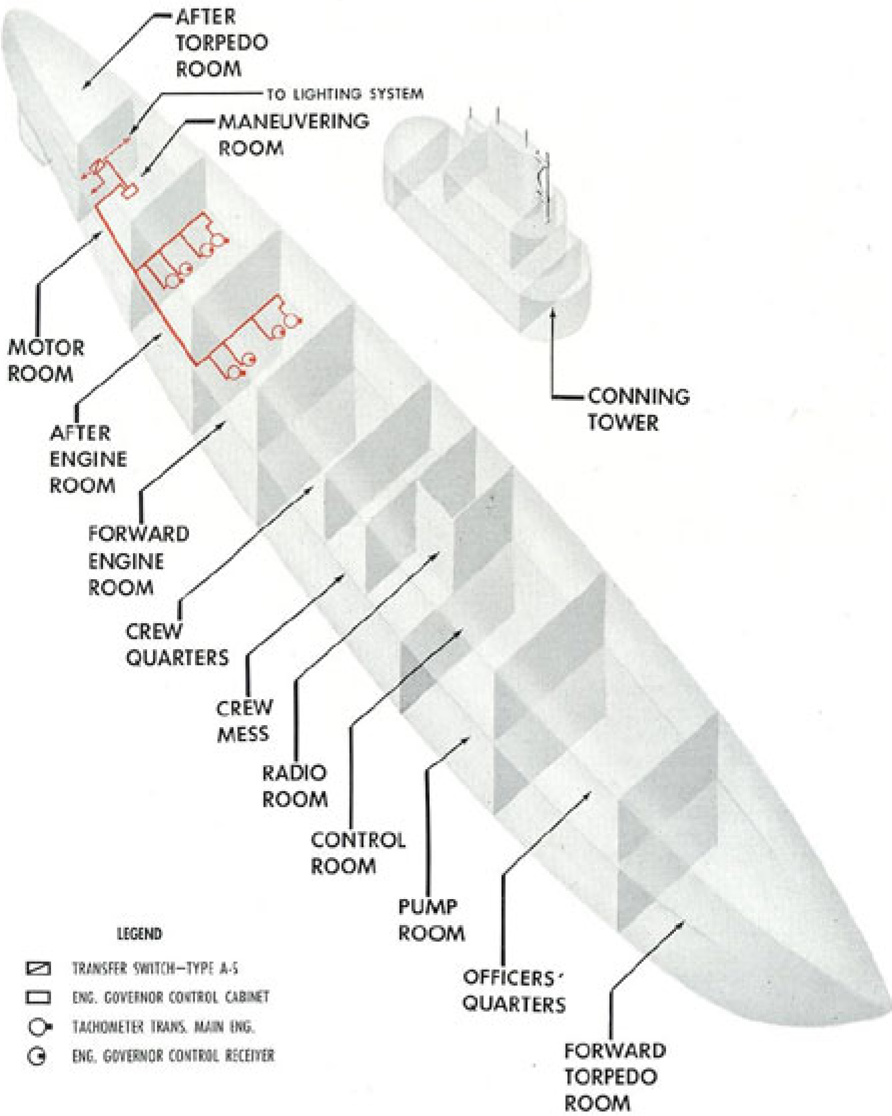

Figure 11-22. Schematic diagram of engine governor control system.

on the shaft. A friction device is also included to prevent too rapid turning of the transmitter. Unlike the a.c. selsyns, none of the effort used to turn the receiver is supplied by the transmitter. It is all supplied electrically.

The receiver consists of a stator, wound as a 2-phase motor as shown in Figure 11-23, and transmitter dial should be matched with the tachometer. This is necessary because the large gear ratio between the dial and the transmitter makes it possible for the transmitter to be synchronized with the receiver at several different positions.

A mechanical clutching device is provided

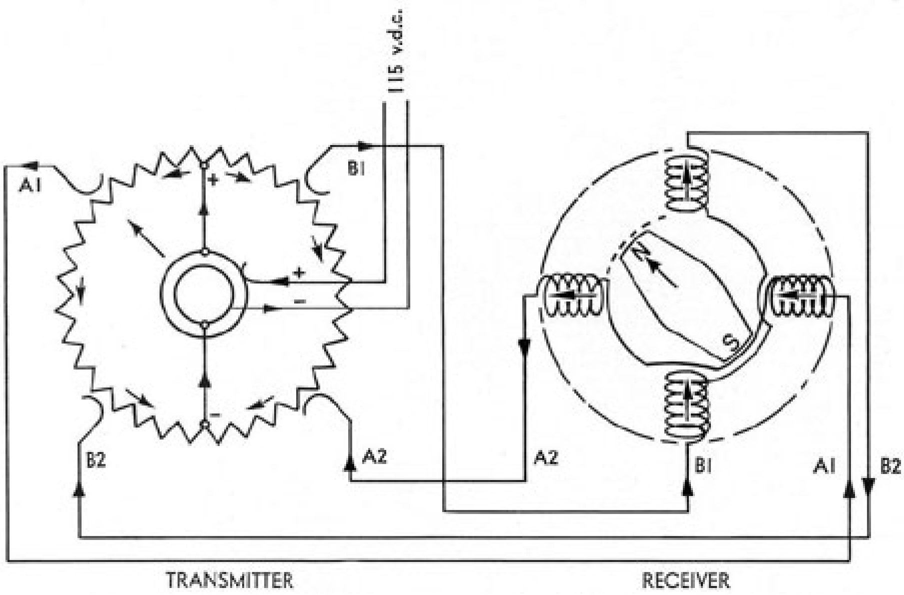

Figure 11-23. Elementary wiring diagram of d.c. governor control, Allis-Chalmers pointer transmitter.

a magnetized solid iron rotor with 2 poles. As the transmitter resistor is rotated, the voltage across each of the 2 windings varies and reverses its direction. The permanent magnet rotor follows until its poles are lined up with the magnetic field which is the resultant of the 2 windings.

11D2. Operation. Each of the governor control units is provided with an OFF-ON switch mounted at the transmitter station. Governor control from the maneuvering room may be cut in or out as desired. Before an engine is started, care should be taken to see that its individual governor control switch is in the OFF position and kept there until the engine room signals READY. Before turning the switch to ON, the by which any single governor control transmitter may be operated individually; or any number of them may be clutched together for common operation through a master control handle.

NOTE. On vessels having split type propulsion control cubicles, the governor control transmitters are also split into 2 cabinets which are somewhat different in operation from those described above. Each cabinet has 3 transmitters and 2 selector switches. The arrangement is such that the third transmitter on either side may be connected to the receiver of either of the engines associated with the other side. It is thus possible to operate any 3 engines in unison. However, it is not possible to operate 4 engines

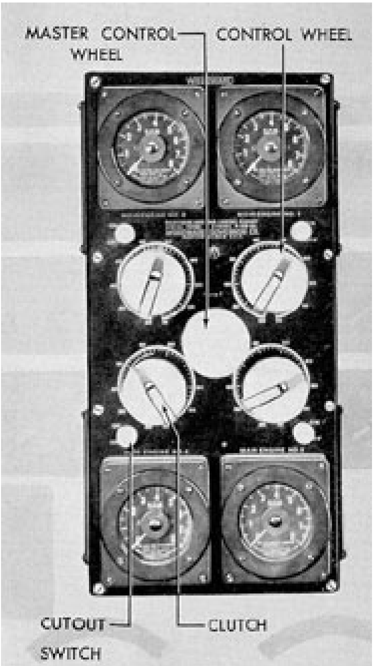

Figure 11-24. Engine governor control panel on main control cubicle.

in unison. This can be done only with the single unit type governor control.

11D3. Maintenance. Maintenance of a.c. selsyn units is described in Section 10B2. For d.c. selsyns, the general comments of Section 10B2 apply, but the symptoms and remedies do not. If the rotor of the receiver sticks, no damage results. If the receiver rotates in the wrong direction, one pair of leads is reversed (A_1 + A_2) or (B_1 + B_2). If it does not rotate in either direction, and is not stuck, the A and B leads

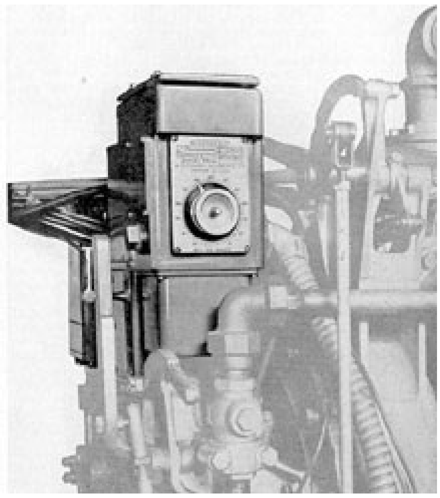
Figure 11-25. Engine governor control unit at engine.

are interconnected; for example A_1 to B_1, and A_2 to B_2.

11D4. Tachometer system. The tachometer system consists of a magnetic generator on each engine and an indicator electrically connected to each of them. The system, by means of a flexible shaft connected to the driving gear of the magneto, also drives a mechanical tachometer located on the engine gage board.

The magneto is mechanically driven by the engine and generates a voltage as a function of its speed. This voltage is impressed on the indicator, which is basically a voltmeter with a scale calibrated in rpm. The 4 indicators are mounted on the engine governor control panel in the maneuvering room.

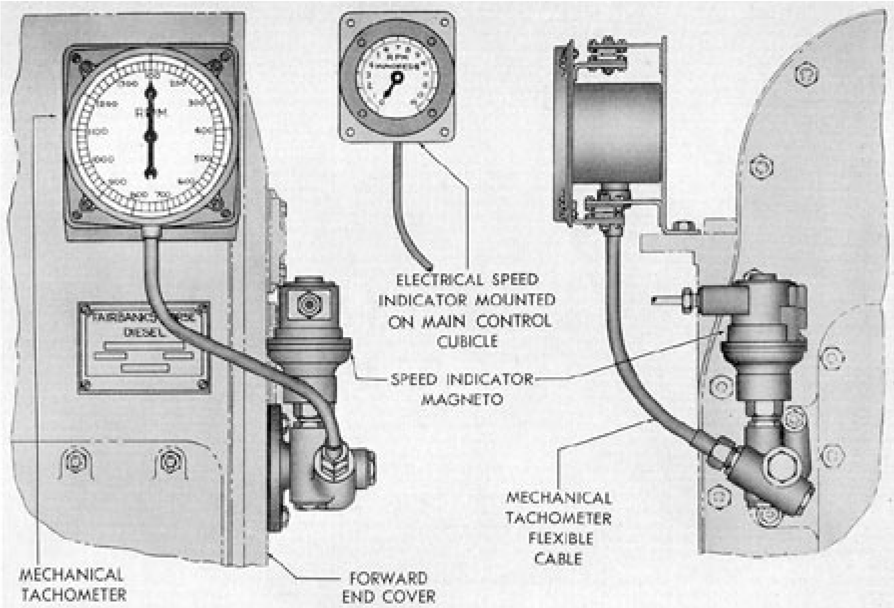

Figure 11-26. Fairbanks-Morse tachometer installation.

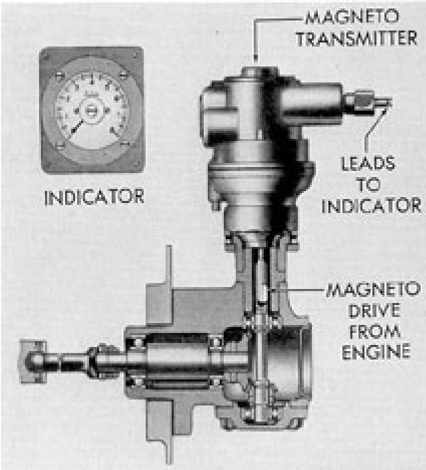

Figure 11-27. Electric Tachometer engine unit and indicator.


Figure 11-28. Weston electric tachometer magneto, engine unit.

12
LOG AND SHAFT REVOLUTION SYSTEMS

A. ROTARY CONVERTER AND CONSTANT FREQUENCY CONTROL UNIT

12A1. Description. The purpose of the constant frequency control unit is to control the speed of rotation of a rotary converter, primary 120-volt d.c., secondary 115-volt, 60-cycle, a.c., and maintain the frequency of the output at exactly 60 cycles for operation of the log and shaft revolution indicator system.

There are two types of constant frequency control units in use, one made by the Pitometer Log Corporation and the other by the Electric Tachometer Corporation. Both units operate on the principle of an electrically driven tuning fork, and are similar in construction. The 60-cycle tuning fork is the prime source of constant frequency.

The rotary converter converts 120-volt direct current to 115-volt, 60-cycle alternating current. This converter, together with the frequency control unit, supplies the constant frequency 60-cycle current necessary for the operation of the synchronous motor in the propeller shaft revolution indicators.

The converter is compound wound with a separate field lead brought out for connection to the rheostat in the constant

12A2. Operation of Electric Tachometer Corporation type unit. The controlled frequency power is obtained from the a.c. output slip rings of a rotary converter and energizes the lower of 2 synchronous motors in the frequency control unit. One side of a mechanical differential is driven in synchronous relation with the converter output frequency by this lower synchronous motor. The other side of the differential is driven in a reverse direction at constant speed by the top synchronous motor. Constant frequency power for this top motor is obtained from a vacuum tube amplifier and its associated tuning fork which is adjusted to vibrate at exactly 60 cycles. Thus, the 60-cycle tuning fork is the prime source of constant frequency which it generates in coils nearest the weighted ends and impresses on the amplifying tube. The fork and amplifier work together; the tuning fork vibrates independently at its own natural frequency and the amplifier keeps the fork vibrating by feeding back some output power. Most of the amplifier power output goes to rotate the top motor at a constant speed corresponding to the frequency of the fork.

frequency control unit. The machine is of drip-proof construction arranged for overhead mounting.

The converter has a 4-pole armature designed for rotation at 1800 rpm. The field is of 4-pole cast iron construction. Another winding on the field is connected to an external resistance.

A centrifugal governor is connected in such a manner that with no external field resistance it regulates the speed of the inverted rotary converter to about 1775 rpm. When the speed of the inverted rotary converter is increased to 1800 rpm by means of field resistance, the contacts of the governor remain closed and the speed control rests with the external resistance in the constant frequency control unit.

A spider arm is operated by the action of the differential and this arm operates a rheostat to control the field current of the inverted rotary converter. The action which takes place is as follows:

When the top and lower motors are running at the same speed, there is no motion of the differential spider arm. This condition exists only when the converter output frequency is the same as, the fork frequency. If the converter falls below synchronous speed, the decreased speed of the lower motor and its half of the differential starts the spider arm revolving. The spider arm turns the arm of the rheostat. The change in position of the rheostat arm changes the converter field current so that the speed and output frequency of the converter are restored to synchronism with the tuning fork. The frequency of the converter output is thus effectively locked

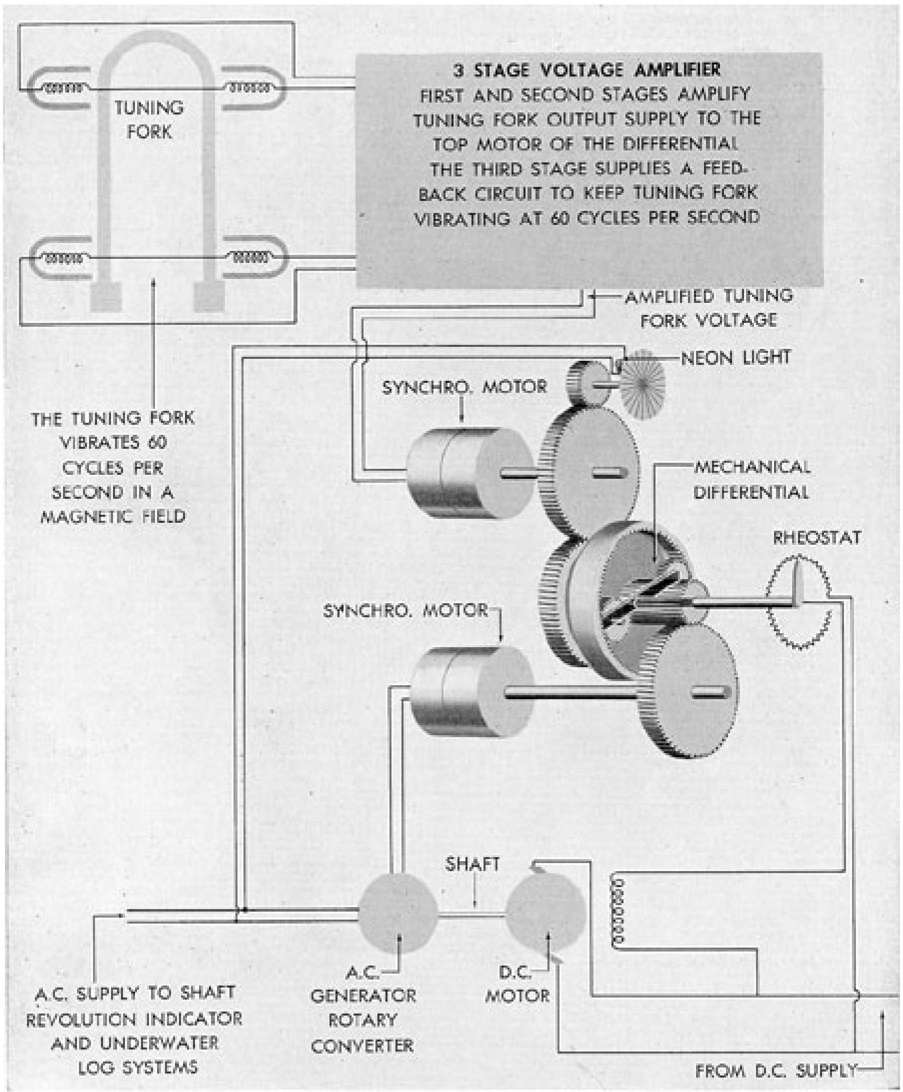

Figure 12-1. Schematic diagram of constant frequency control unit.

in synchronism with the tuning fork frequency. This condition is true in spite of changes in load on the converter, temperature-resistance changes in the windings, or +- 10 percent variation in the d.c. voltage supply to the converter.

A stroboscope disk, driven by the top motor at tuning fork frequency, gives visual indication of a gain or loss in converter speed. Normally the radial lines of the stroboscope disk appear to be stationary because the flashes of light from

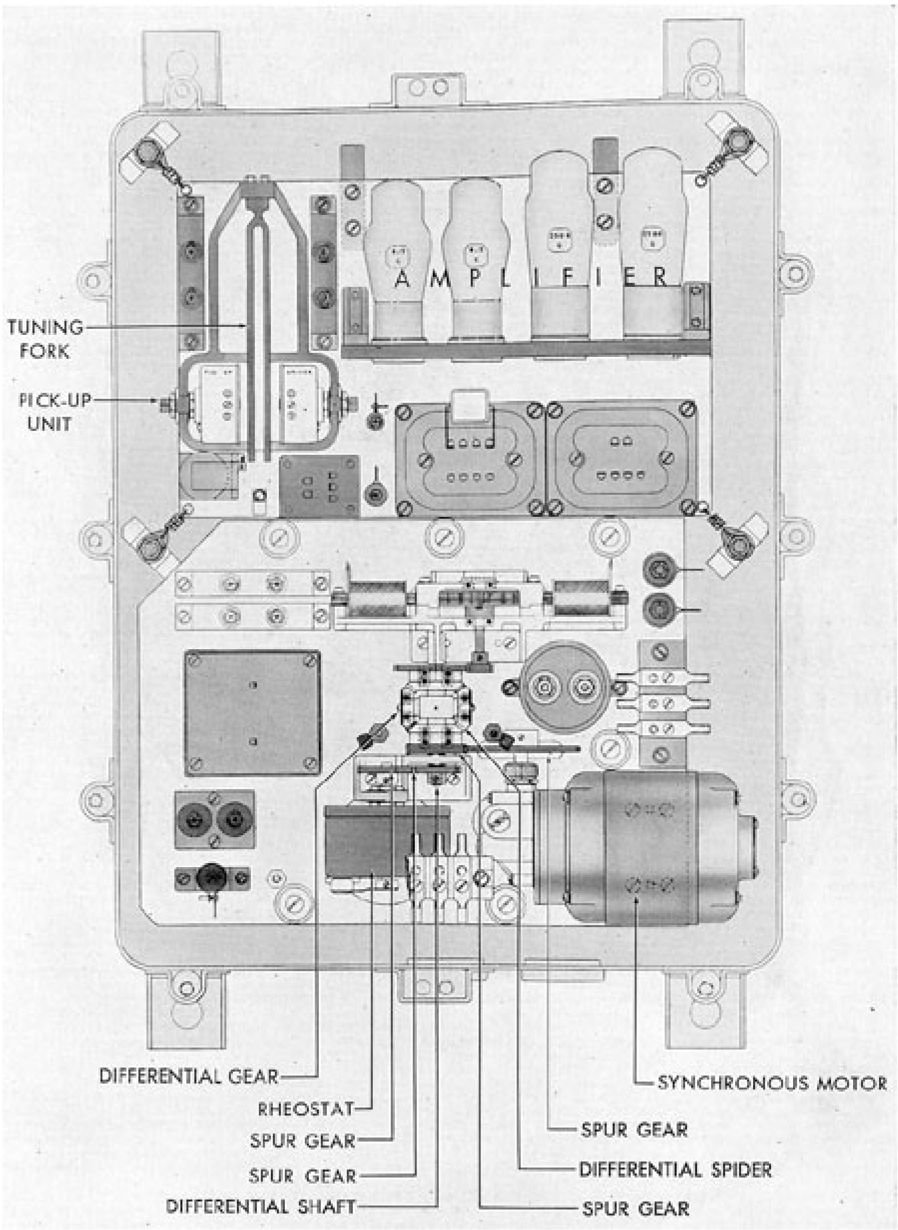

Figure 12-2. Frequency control unit, Pitometer Log Corporation type.

the stroboscope lamp connected to the output frequency are in synchronous relation to the constant speed of the disk. If the converter gains or loses, the change in the rate of flashes creates the illusion of turning of the disk. At the same time, the differential spider arm does actually turn, due to the changed speed of the lower motor. If for any reason the apparatus fails to correct the change in speed, an alarm is energized to show that the unit has lost control. The stroboscope disk is intended as a minute. When the stroboscope disk shows that the converter is in synchronism, the clock serves as a check on the fork. The operation of the Pitometer Log Corporation control unit is identical, except that the tuning fork is started by a magnet and clapper controlled by the line switch. The units are described in detail in the manufacturer's instruction book.

12A3. Maintenance. It is necessary that the brushes and commutator of the converter be kept clean and the brushes set for

relative check of converter and fork frequency. A clock is provided as a means of checking the absolute or real value of the converter frequency. When the generated output frequency is 60 cycles, the hand of the clock makes 1 revolution per minimum sparking under normal load. Detailed maintenance instructions for bearings, gears, and tubes may be found in the manufacturer's instruction book.

B. UNDERWATER LOG SYSTEM

12B1. Description. The underwater log system consists of the equipment required for indicating the speed of the submarine and the distance traveled through the water. Each of the various types of underwater log systems in service requires a rodmeter which projects out through the pressure hull of the submarine, and mechanisms for converting into a speed indication the differences between the dynamic pressure of the water caused by the forward motion of the ship, and the surrounding static pressure. Each of the systems also has a mechanism for integrating speed with respect to time to indicate the total distance traveled. The system requires 115-volt, 60-cycle, single-phase, alternating current for operation and is designated as circuit Y.

The mechanical and electrical units of the underwater log system are actuated by water pressure obtained through the rodmeter. The rodmeter has 2 passages and extends into the water a distance of about 3 feet. Being located at the forward part of the ship, it is in relatively smooth-flowing water, since the water at this point is least affected by the movement of the forward passage of the rodmeter. This added pressure is known as dynamic pressure. The difference between these pressures is the actuating force that operates the system.

The method used to convert the dynamic pressure into indications of speed and distance differs as follows in the three underwater log systems used in service.

1. Rotary balance type underwater log system. An underwater log system of the rotary balance type employs a rotary balance unit consisting of an automatically controlled motor-driven centrifugal pump that develops a pressure to oppose the dynamic pressure from the rodmeter. The pump is connected to the dynamic passage of the rodmeter and to the inner part of a sensitive bellows assembly. The outside of the bellows assembly is connected to the static passage of the rodmeter. Pressure differences between the passages in the bellows cause it to expand or contract, thereby moving a rod which in turn actuates a motor driving a rheostat. This rheostat controls the speed of the pump motor and is known as the transtat assembly. Any increase or decrease in dynamic pressure caused by variation of the ship's

ship or by the turbulence created by action of the propellers. When the ship is at rest, the water pressure is equal in both passages of the rodmeter and is due only to the weight of the water above the system. This pressure is known as static pressure. As the ship moves forward, the movement creates additional pressure in the speed causes a movement of the transtat arm, resulting in a change in speed of rotation of the pump drive motor. The speed of rotation of the pump motor therefore, is always proportional to the speed of the ship through the water.

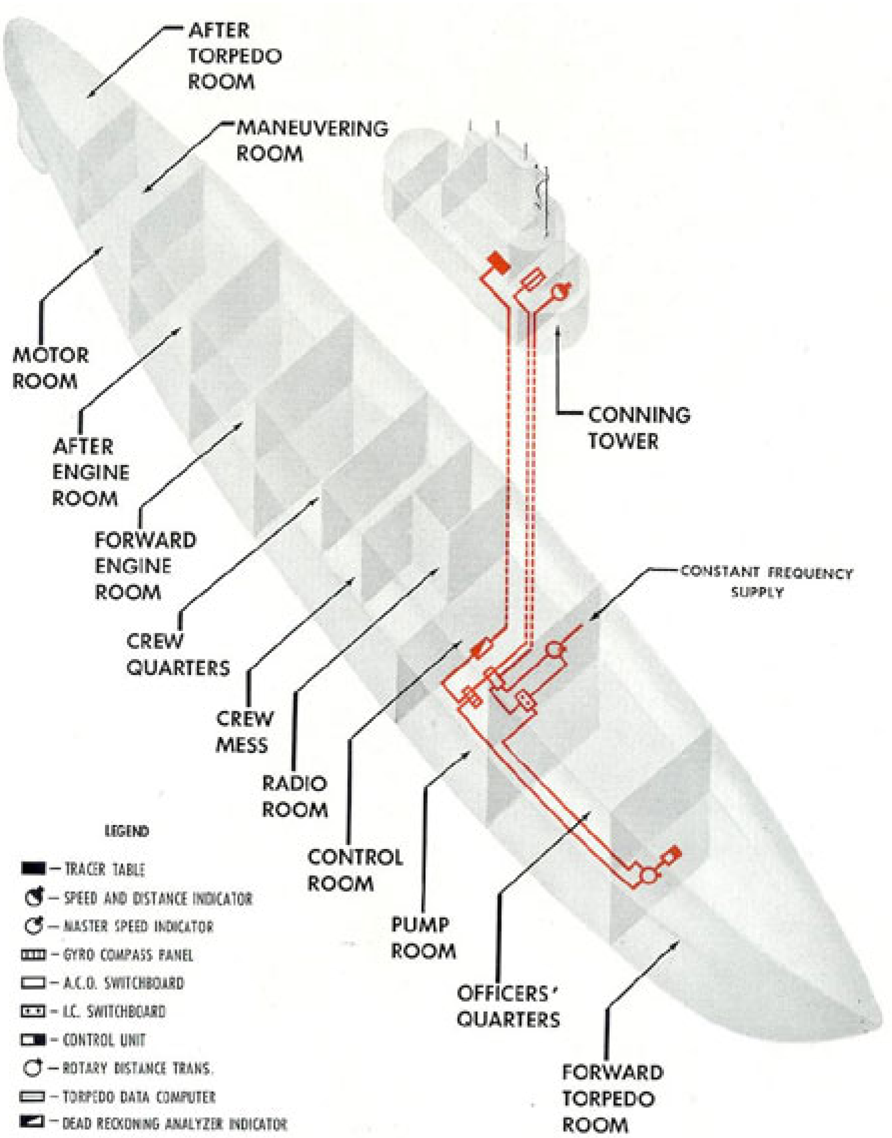

Figure 12-3. Schematic diagram of underwater log system.

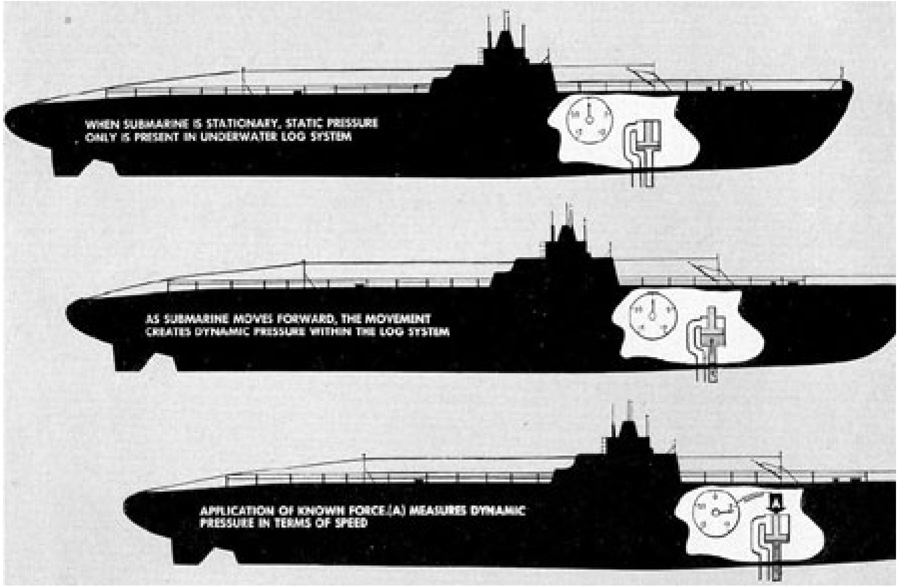

Figure 12-4. Elementary diagram showing fundamental principle of operation of underwater log system.

The pump motor shaft is geared to a selsyn transmitter by means of which rotary motion proportional to the speed of the ship is conveyed to 2 selsyn indicators. One of these indicators is geared to a mechanical counter in the master speed indicator which registers the total distance traveled in miles. This same selsyn indicator, through suitable gearing and in conjunction with a time element derived from the constant frequency a.c. supply, operates a pointer that shows the speed of the ship in knots. The other selsyn indicator driven by the pump motor transmitter operates a mechanical counter in the remote speed and distance instruments. Remote indications of the ship's speed are transmitted by a selsyn transmitter in the master speed indicator driven by the miles per hour pointer shaft. Speed input to fire control and navigational equipment is obtained from this same transmitter.

2. Mercury manometer type underwater log system. The mercury manometer type of of bellows as the means of actuating the mechanism for indicating the speed and distance traveled.

The mercury manometer consists of 2 tubes containing mercury. They are connected at the top to the dynamic side of the rodmeter. A pipe line connects the 2 manometer tubes at the bottom ends and has an opening in the center to allow mercury to enter a chamber containing a float. The static pressure is admitted into the top of this float chamber. Any change in dynamic pressure causes a change in the level of the mercury in the float chamber, thus causing the float to position itself accordingly. A rack attached to the top of the float drives a gear coupled in turn to the main shaft of the transmitter mechanism.

The transmitter mechanism is the master speed and distance indicator as well as the transmitter for remote indications. The main shaft of the transmitter mechanism is directly connected to the master speed dial. Thus, the master speed dial is positioned directly by the

underwater log system installed in some older submarines uses a mercury manometer instead

movement of the mercury in the float chamber

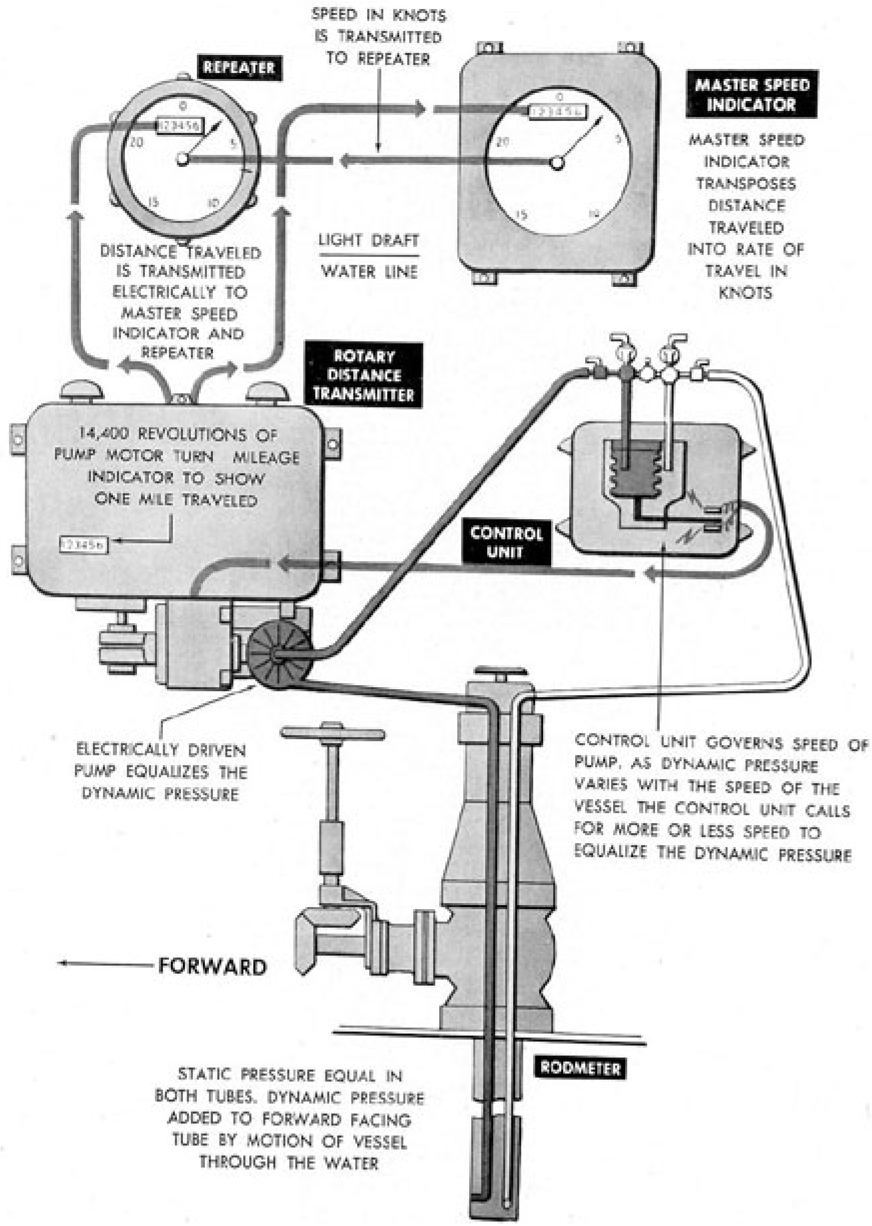

Figure 12-5. Schematic diagram of rotary balance type underwater log system.

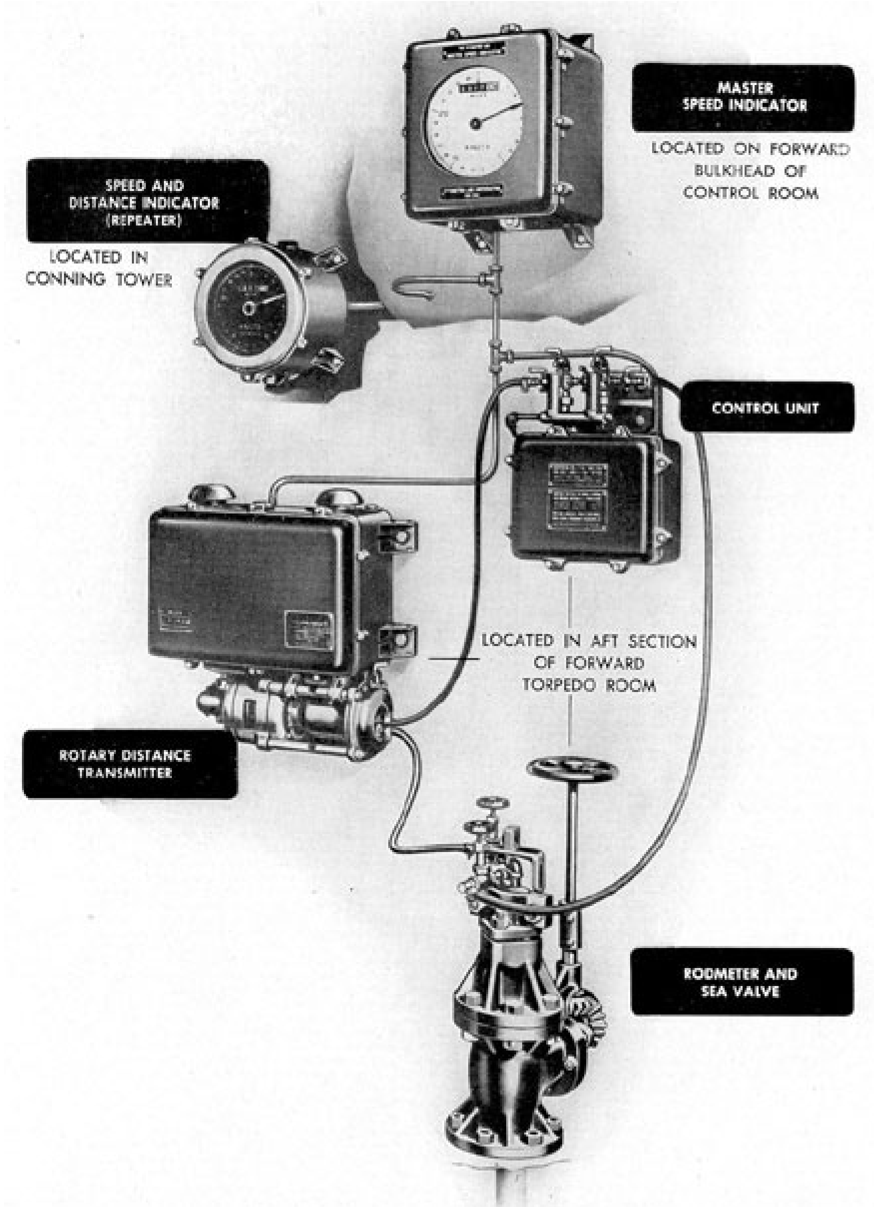

Figure 12-6. Arrangement of units of rotary balance type underwater log system.

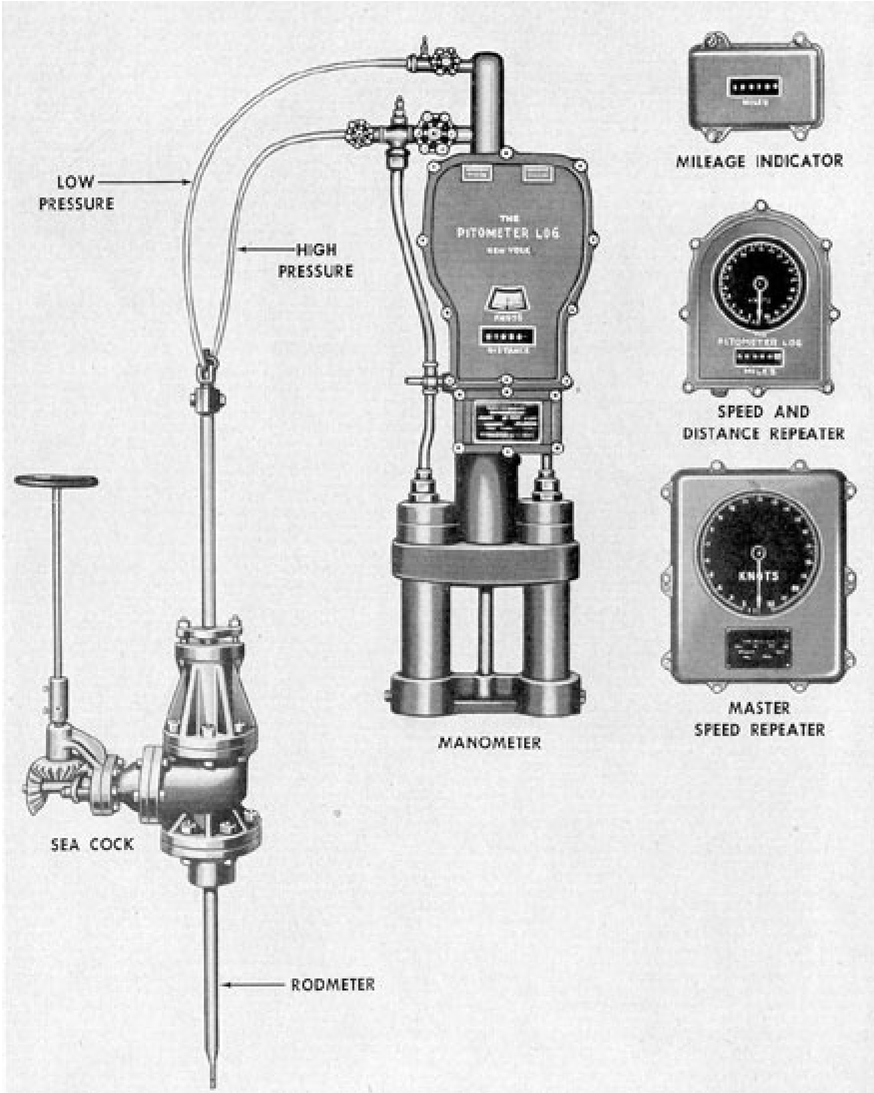

Figure 12-7. Pitometer log mercury manometer type units.

and indicates the correct speed without any electrical connection. The speed indication is transmitted to speed repeaters in the control room and conning tower by means of selsyn units.

Distance indication is obtained from the speed element by means of a mechanical integrator using constant frequency input as a time element. It is transmitted to the control room and conning tower through selsyn units.

3. Bendix type underwater log system. The Bendix type underwater log system is actuated by the expansion and balance arm spring tends to aid the main force arm in returning to the NEUTRAL position. The function of this auxiliary balance arm and connecting spring is to permit setting of a calibration correction that is dependent upon the speed and to affect the neutral point at which the main balance arm settles for each speed.

The driving gear for the speed transmitter is in mesh with the gear of the cam and gear combination driven by the actuator motor. The transmitter is a conventional selsyn unit connected to speed indicators in the conning tower and control room.

contraction of a bellows similar to the assembly used in the rotary balance type system. When a change in dynamic pressure occurs, the bellows move a diaphragm to which is attached a bellows rod. Movement of the bellows rod actuates a main balance arm that carries a contact maker. Any movement of the main balance arm and its associated contact maker closes the circuit to an actuator motor. This actuator motor in turn drives a combination cam and gear in the center of which is mounted the speed pointer.

The main balance arm is attached by a coil spring to another arm, known as the main force arm. Approximately at the midpoint of the main force arm is an extension with a cam roller on its extreme end. This cam roller at all times rides on the cam part of the cam and gear combination driven by the actuator motor. The resulting pressure of the cam on the cam roller causes the main force arm to swing in a direction opposite to the original movement of the main balance arm. This motion tends to return the main balance arm to the neutral position due to the spring tension between the two arms. At this point the actuator motor contact is broken, the motor stops, and the combination cam and gear with its attached speed pointer remains in its assumed position.

The auxiliary balance arm is connected to the main balance arm by means of a spring and swings independently of it. It is positioned by the setting of the

Distance indication is obtained from the master speed indicator by means of a mechanical integrator using constant frequency input as a time element and is transmitted to the control room and conning tower through selsyn units.

12B2. Operation. After the rodmeter is lowered, the complete system is placed in operation by turning switches marked 1Y, 2Y, and 3Y, located on the I.C. switchboard, to the ON position. When switch 1Y is closed, speed indications are transmitted to the conning tower and control room. This switch also completes the circuit for the speed input to the torpedo data computer, gyrocompass, and dead reckoning indicator. Switch 2Y completes the circuit from the 115-volt a.c. bus to the selsyn transmitter for distance indications in the conning tower and control room.

Switch 3Y completes the circuit from the controlled frequency a.c. bus to the synchronous motor (time element) in the master instrument in the forward torpedo room or control room.

12B3. Maintenance. Adjustment or repairs should not be attempted without reference to the manufacturer's instruction book for specific instructions.

NOTE. Complete and detailed information on all phases of the theory, operation, and maintenance of the log may be found in Submarine Underwater Log Systems, NavPers 16168.

adjustment on the guide slot and
by means of the lead screw
driven by the actuator motor.
Tension on the auxiliary

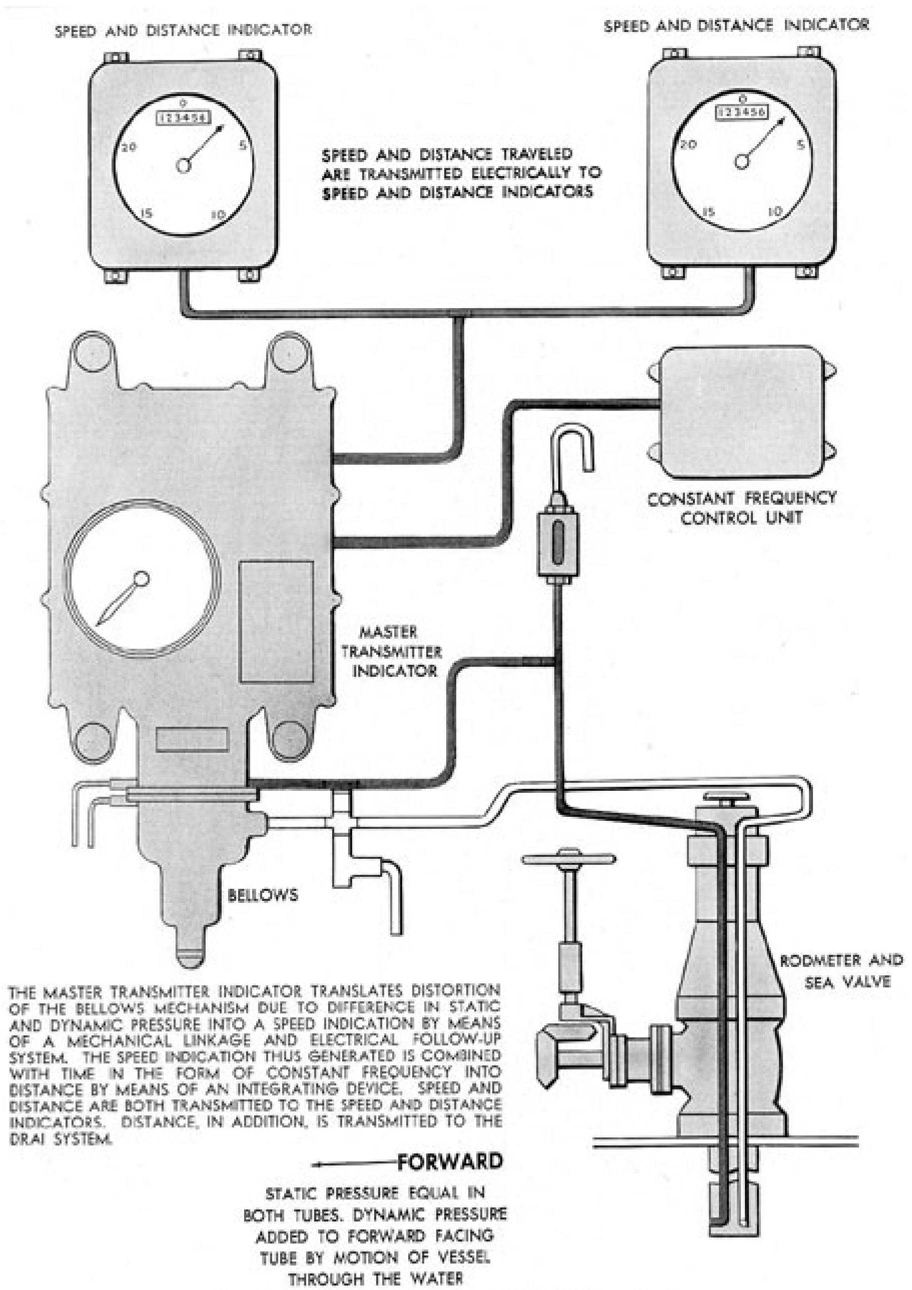

Figure 12-8. Schematic arrangement of Bendix bellows type log.

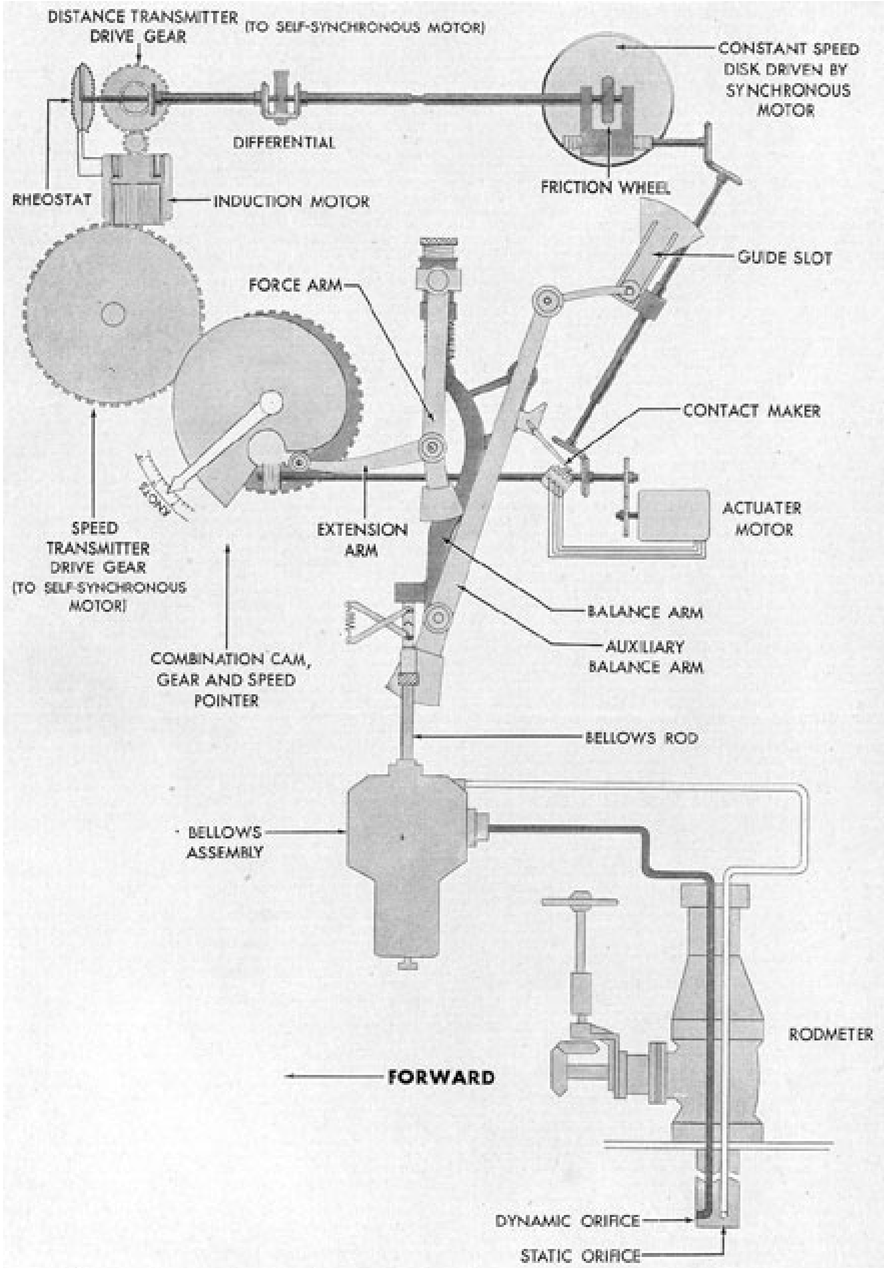

Figure 12-9. Schematic diagram of Bendix underwater log master transmitter Indicator.

C. PROPELLER SHAFT REVOLUTION INDICATOR AND COUNTER SYSTEM

12C1. Description. a. General. The purpose of the propeller shaft revolution indicator and counter system is to transmit indications of propeller rpm and total revolutions from the propeller shafts to the control station in the maneuvering room. The system is designated types of shaft revolution indicator and counter systems in service are the same. The indicator units, however, while employing the same principle of operation, differ considerably in construction and detail.

c. Indicator units. 1. Electric Tachometer Corporation type. The

as circuit K and consists essentially of the following parts:

1. Transmitters located in the motor room and geared to the propeller shafts.

2. Indicators in the maneuvering room at the control station. These indicators have a pointer to indicate rpm, a counter to indicate total shaft revolutions, and a backing signal. The system operates on a constant frequency power supply of 115-volt, 60-cycle, single-phase, alternating current obtained from the constant frequency control unit through fused switches on the I.C. switchboard.

b. Transmitters. Each of the transmitters in the motor room consists of a conventional selsyn transmitter geared to its respective propeller shaft, which transmits rpm indications to its allied indicator in the maneuvering room. In the watertight cases containing the transmitter units is a simple mechanical counter. It is chain driven by the transmitter shaft and indicates total shaft revolutions. The transmitters are designed to operate in only one direction and carry a unidirectional device that maintains a constant direction of rotation regardless of the direction of rotation of the propeller shafts.

The visual backing signal in the maneuvering room indicator is actuated by a pair of contacts located at the top of the unidirectional device. Normally, these contacts are open and no signal is indicated. When the selsyn indicator (motor) (Figure 12-12) actuated by the transmitter in the motor room carries spiral gears on its shaft. These gears drive a screw shaft in a constant direction and at a speed proportional to the speed of the propeller shaft. Threaded on the screw shaft is a nut to which is attached a friction wheel. The rim of this friction wheel is always in contact with a friction disk below it. The friction disk, driven at a constant speed of 96 rpm by a synchronous motor, is pressed against the edge of the friction wheel by a spring. Thus, when the friction wheel is in the center of the friction disk, it is held stationary, but, as it is moved outward by the rotation of the screw shaft in the nut, it begins to rotate. The speed at which it rotates is dependent upon its position on the face of the friction disk. As long as this speed is less than the speed of the screw shaft, the wheel and nut continue to move outward until the wheel reaches a spot on the friction disk where its speed is equal to the speed of the screw shaft. At this point there is no longer any tendency for the nut and friction wheel to move along the screw shaft, and the wheel rides on a circle of radius exactly proportional to the propeller shaft speed.

The rotating nut carries with it, on ball bearings, a rack sleeve that is restrained from turning. Along the side of this sleeve is a rack gear meshing with a small pinion on the shaft carrying the pointer. The pointer comes to rest at a position determined by the finally balanced position of the friction wheel, and thus indicates on a properly

propellers rotate in the reverse direction, the arm carrying the reversing gears in the unidirectional device closes the contacts, thereby actuating a magnet which pulls into view a white letter B in a red field signifying back rotation of the propeller shaft.

Essentially, the transmitter units of the two divided scale, the rpm of the propeller shaft.

The indicator unit also contains a mechanical revolution counter. The counter is gear-driven off the end of the screw shaft and indicates total shaft revolutions.

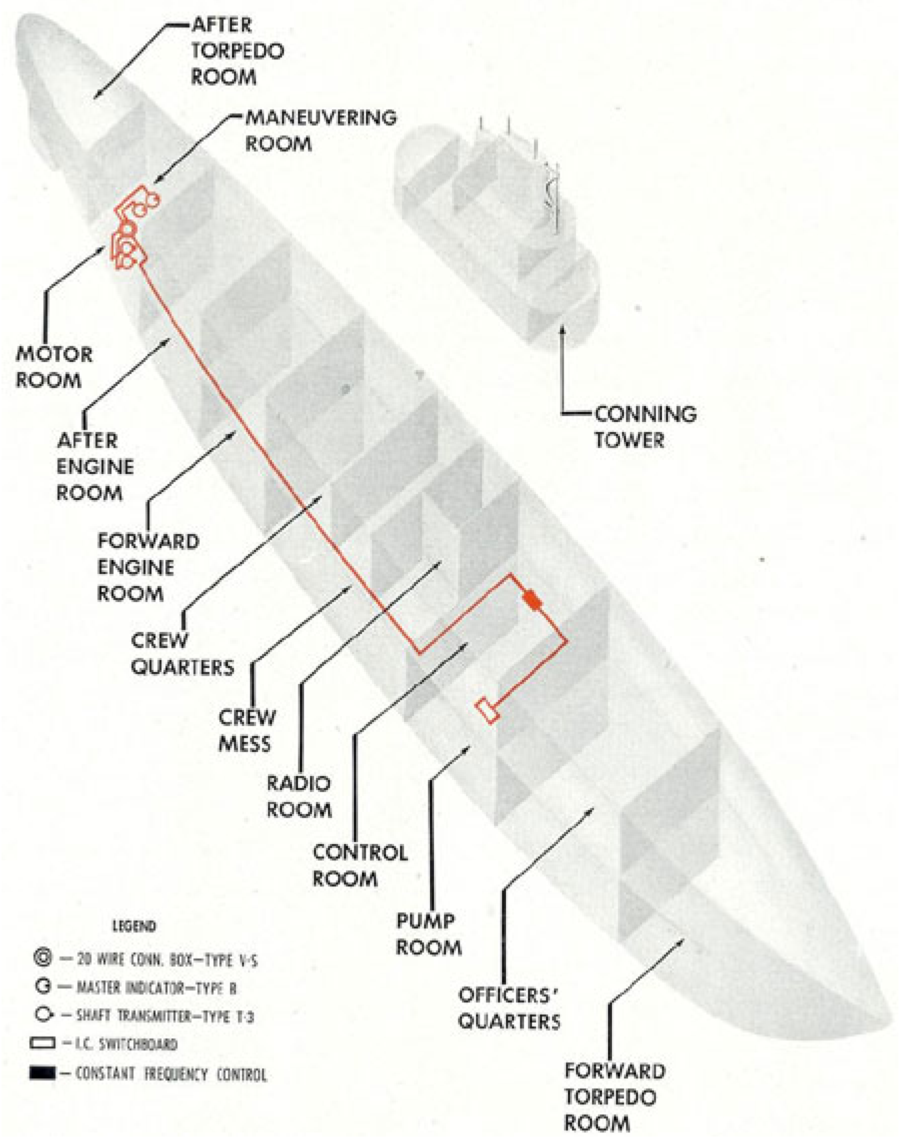

Figure 12-10. Schematic diagram of propeller shaft revolution Indicator and counter system.

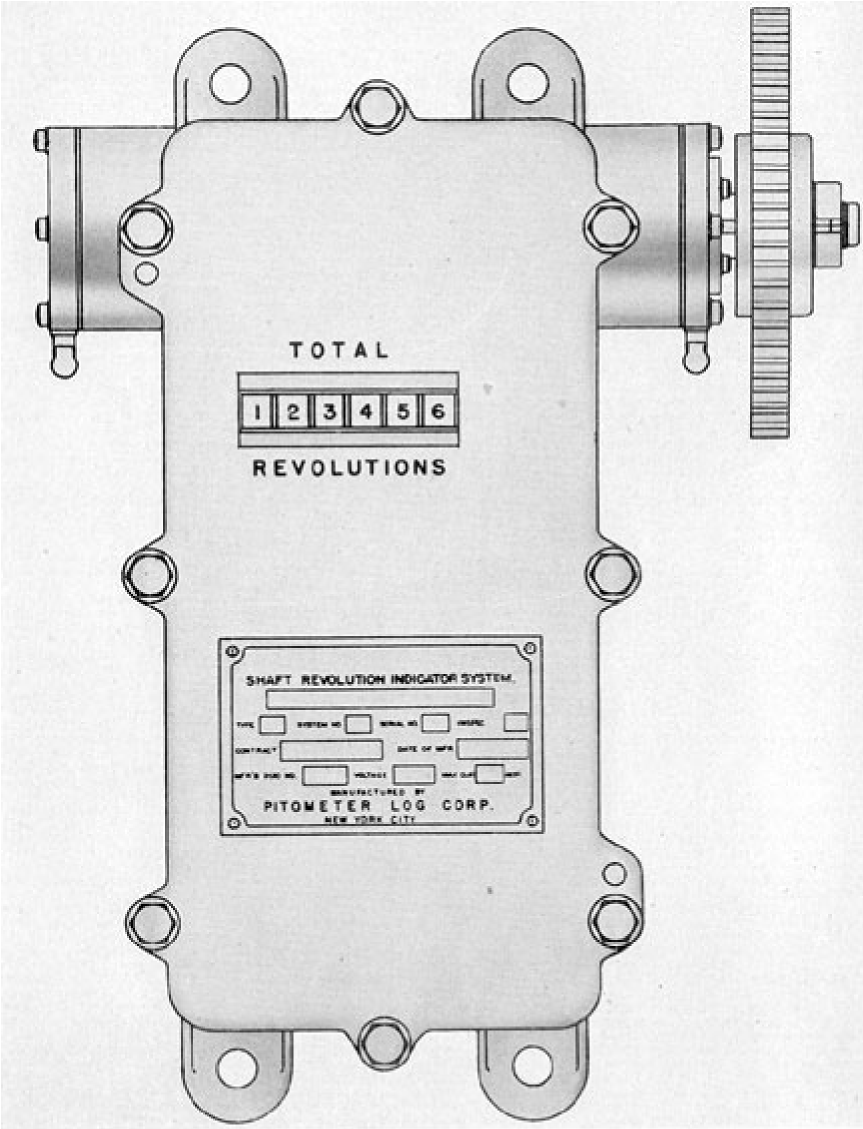

Figure 12-11. Pitometer log type of shaft revolution transmitter.

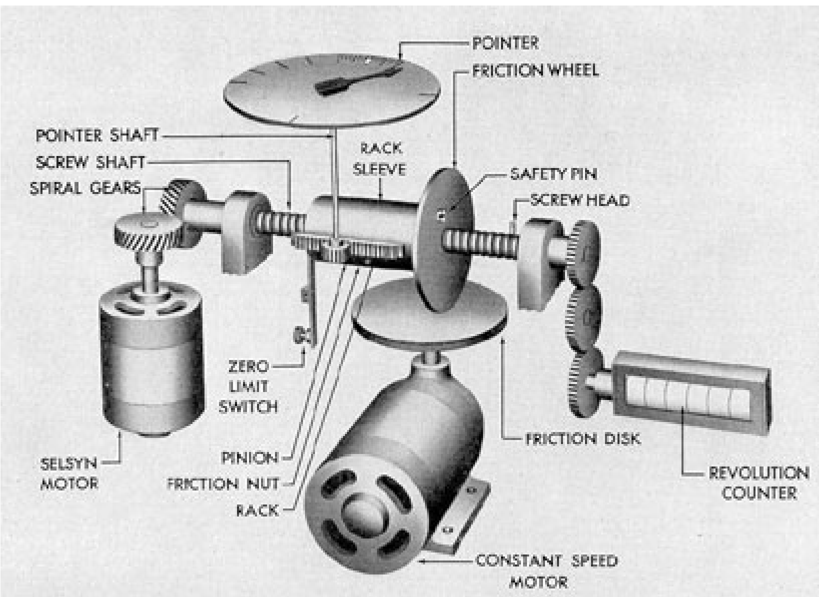

Figure 12-12. Schematic arrangement of Electric Tachometer Corporation type indicator and counter system.

2. Pitometer log type. The Pitometer log type indicator

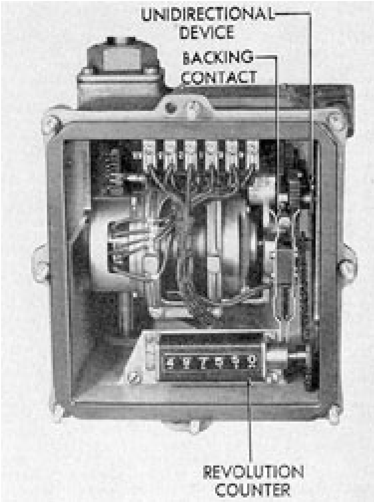

Figure 12-13. Top view of propeller shaft revolution transmitter, Electric Tachometer Corporation type with cover removed.

(Figure 12-15) operates on the same principle as the Electric Tachometer type. The essential difference in construction is that the indicator shaft drives one half of a differential gear assembly and the friction disk drives the other half. The screw shaft is rotated by a separate reversible motor and moves the friction wheel across the face of the friction disk in a manner similar to that of the Electric Tachometer instrument. The friction disk is driven by a constant speed synchronous motor at a speed of 100 rpm. The screw shaft driving motor is started, stopped, or reversed by a set of contacts mounted on the shaft that carries the pinion gear of the differential assembly. When the indicator motor begins to rotate its half of the differential, a movement of the pinion gear results because the other half of the differential is stopped, or is rotating very slowly. Movement of the pinion gear closes the contacts for the screw shaft driving motor, causing the friction wheel assembly driving the other half of the

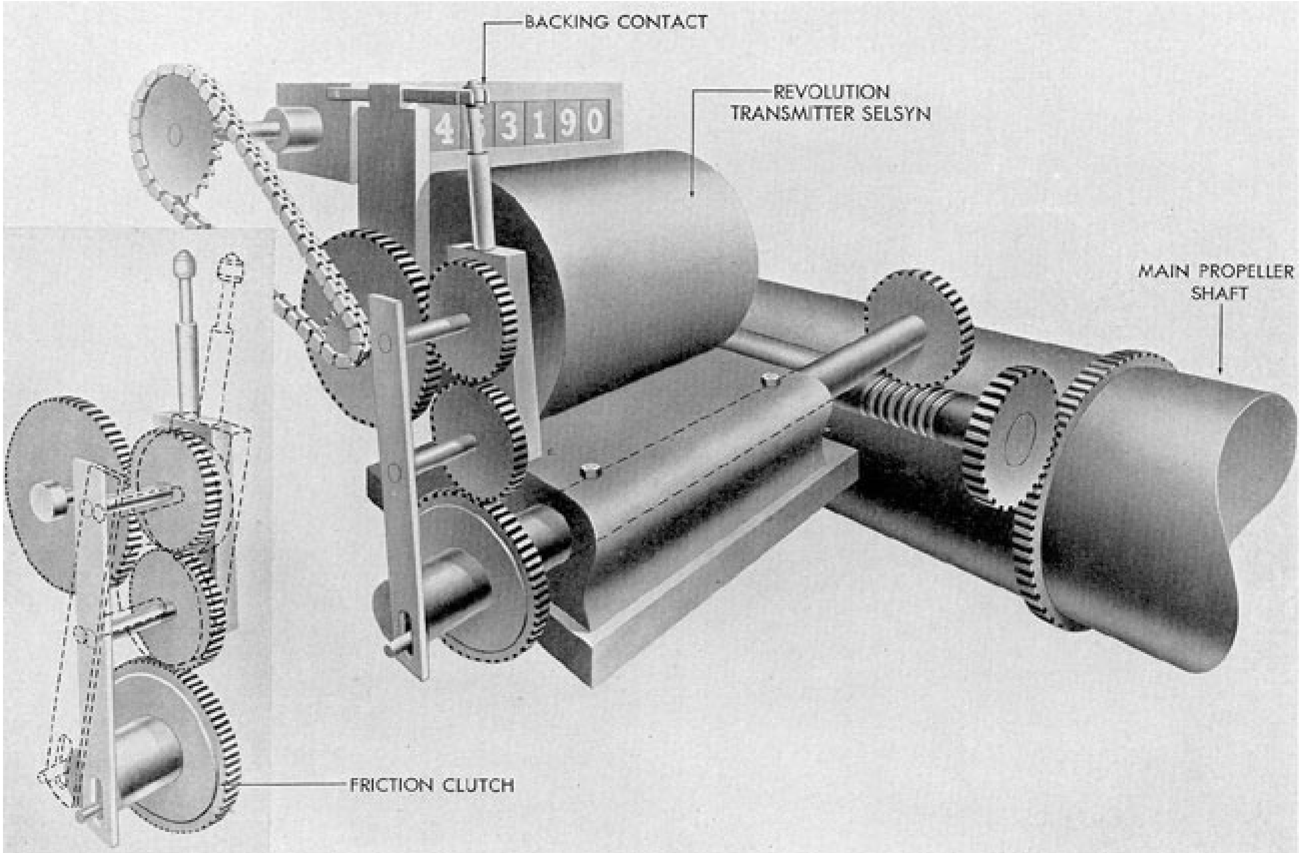

Figure 12-14 Schematic arrangement of shaft revolution transmitter.

differential to move outward across the friction disk. This movement of the friction wheel away from the center of the friction disk causes the wheel and its associated differential gear to rotate at a constantly increasing speed. This speed continues to increase until it is equal to the speed of the other half of the differential. When the point is reached at which there is no more turning effect imparted to the pinion gear, the contacts operated by the pinion gear shaft open and the screw shaft driving motor stops. The friction wheel assembly is then positioned on the friction disk and remains there until a change in propeller shaft speed again causes a mechanical unbalance of the differential.

12C2. Operation. The system is placed in operation by turning switches marked 1K and 2K on the I.C. switchboard to the ON position. These switches energize the circuits to the starboard and port transmitters. Switches 8K1 and 8K2, also on the I.C. switchboard, must be turned to the ON position in order to energize the circuits from the constant frequency bus to the starboard and port synchronous motors which drive the friction disks.

NOTE. If the synchronous motor circuits are not energized, there will be no force to prevent the friction wheel from traveling to the extreme outer edge of the friction disk, thus causing the instrument to indicate maximum rpm regardless of the speed of the propeller shaft.

The pointer shaft is directly geared to the screw shaft and gives a steady indication of propeller rpm on a properly divided scale.

The indicator motor also drives, through gearing, a mechanical counter which indicates total shaft revolutions.

12C3. Maintenance. When the propeller shafts are stopped, the friction wheel should not

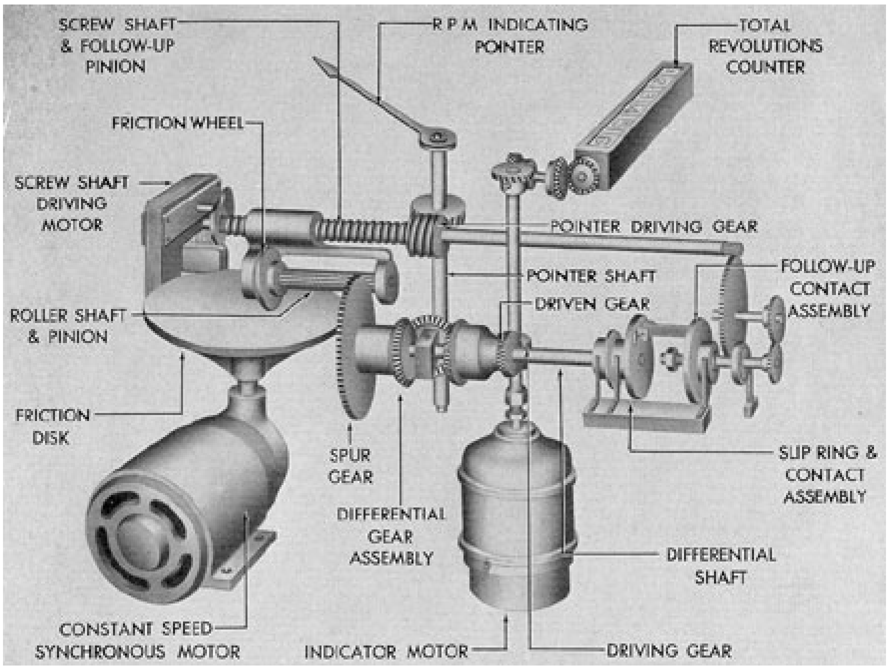

Figure 12-15. Schematic arrangement of Pitometer log type propeller shaft revolution indicator and counter system.

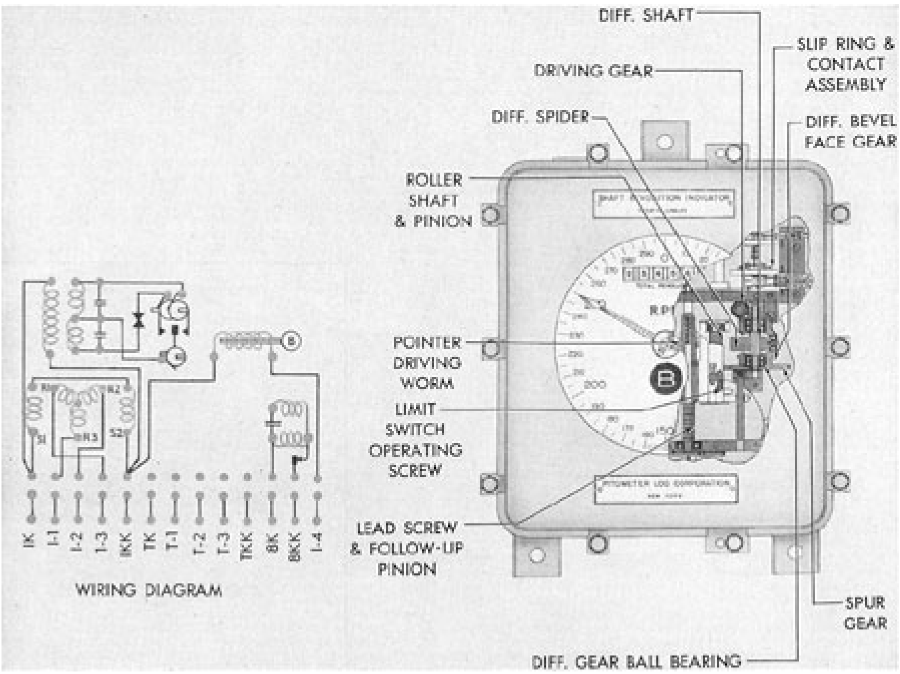

Figure 12-16. Details and wiring diagram of Pitometer log type master indicator.

be in such a position as to

indicate zero rpm. It should indicate between 2 and 4 rpm. In order to indicate zero, the friction wheel would have to come to rest at the exact center of the friction disk, and the revolution of the disk would impart a twisting motion to the rim of the friction wheel. The resulting friction would grind a flat spot on the rim of the wheel and a depression in the center of the disk.

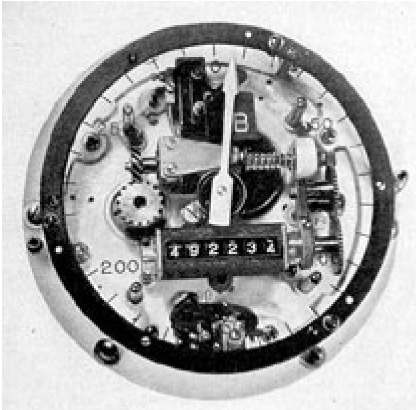

Figure 12-17. Shaft revolution indicator, Electric Tachometer Corporation type, with face removed.

No adjustments, lubrication, or repair should be attempted without reference to the detailed instructions contained in the manufacturer's instruction book.

12C4. Propeller revolution indicator system, magneto type. Late design submarines employ a very simple revolution indicator system based on the magneto voltmeter principle (see Figures 12-18 and 12-19). Geared to each propeller shaft is a small, enclosed, permanent magnet magneto of the 2-wire d.c. type which transmits a direct current proportional to the

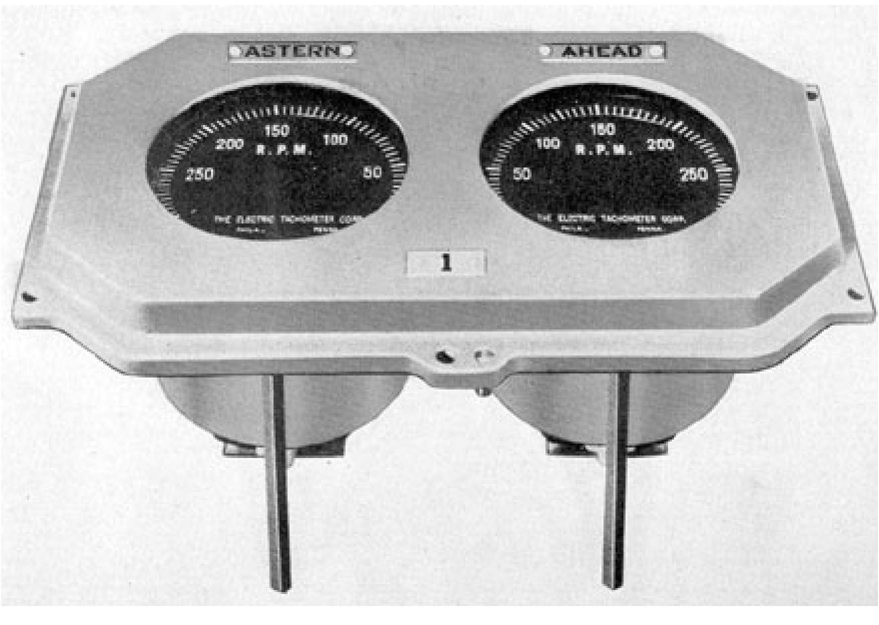

Figure 12-18. Shaft revolution indicator, magneto type, maneuvering room indicator.

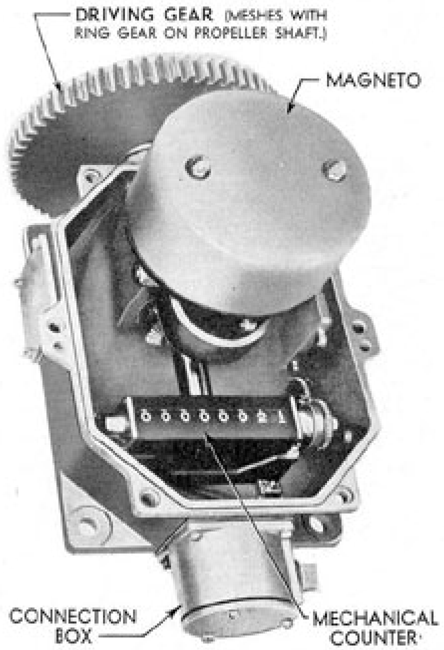

Figure 12-19. Shaft revolution indicator, magneto type, shaft transmitter, with cover removed.

rotational speed of the shaft. A mechanical counter indicating only total ahead turns is built into the same housing as the magneto. The indicator for each shaft consists of 2 voltmeters mounted in a simple housing on each side of the control cubicle, one being calibrated for and reading ahead speed, and the other reading astern speed for that shaft. The system resembles the engine tachometer system. It requires no external source of energy, and connecting it to any source of power will damage the instrument.

13
MISCELLANEOUS SYSTEMS

A. ENGINE ORDER INDICATOR SYSTEM

13A1. Description. The engine order indicator system is composed of 4 rotary transmitter switches and 4 sets of indicating lights in the maneuvering room, and 2 rotary transmitter switches with 2 sets of indicator lights in each engine room. The purpose of the system is to transmit orders for engine operation between the maneuvering room and engine rooms.

The circuit designation is 3MB and it is energized from the ship's 120-volt d.c. supply taken either from the d.c. bus of the I.C. switch board, or directly from either the port or starboard lighting feeder, depending upon the type of installation.

13A2. Operation. The maneuvering room transmitter unit has a rotary selector switch for each main engine with positions marked STOP, START, OFF, CUT-IN, and CUT-OUT. The 4 indicator reply lights in the maneuvering room for each main engine are marked START, STOP, READY, CUT-OUT. A push button on the transmitter operates a bell in each engine room.

The double indicator in each engine room has 4 indicator reply lights for each engine. They know that orders were correctly received, the rotary transmitter switch in the engine room is used to acknowledge orders. This switch is marked STOP, START, OFF, READY, and CUT-OUT.

Following is a normal sequence of signals transmitted in starting an engine:

1. The maneuvering room turns the rotary switch to START, thereby lighting the START lamp in the engine room indicator.

2. The engine room acknowledges by turning the rotary switch to START, thus lighting the START lamp in the maneuvering room indicator.

3. The engine room signals READY to the maneuvering room. This indicates that the engine is running and that they are ready to turn over governor control.

4. The maneuvering room signals CUT-IN, indicating that they are taking over governor control. If at any time during the engine's operation, the engine room signals CUT-OUT, it means that the engine room desires the load to be removed from the engine and wishes to have governor control. The maneuvering room acknowledges the order by signaling CUT-OUT.

are marked START, STOP, CUT-IN, CUT-OUT. The orders received from the maneuvering room are shown by this double indicator. In order that the maneuvering room may

B. LUBRICATING OIL AND ENGINE CIRCULATING WATER ALARM SYSTEM

13B1. Description. The lubricating oil (low pressure) and engine circulating water (high temperature) alarm system is composed of pressurestatic and thermostatic contact makers which under certain conditions close a circuit and provide an indicating signal.

Pressurestatic contact makers are installed in the lubricating oil lines to all main engines and to the auxiliary engine, and in the lubricating oil supply between the reduction gears and main motor bearings.

A pressurestat is essentially an automatic contact maker consisting of a metal case in which the lower portion is sealed into an oil tight chamber by means of a diaphragm. The upper side of the diaphragm carries the movable portion of the contact maker. Oil from the line is led to the lower chamber under working

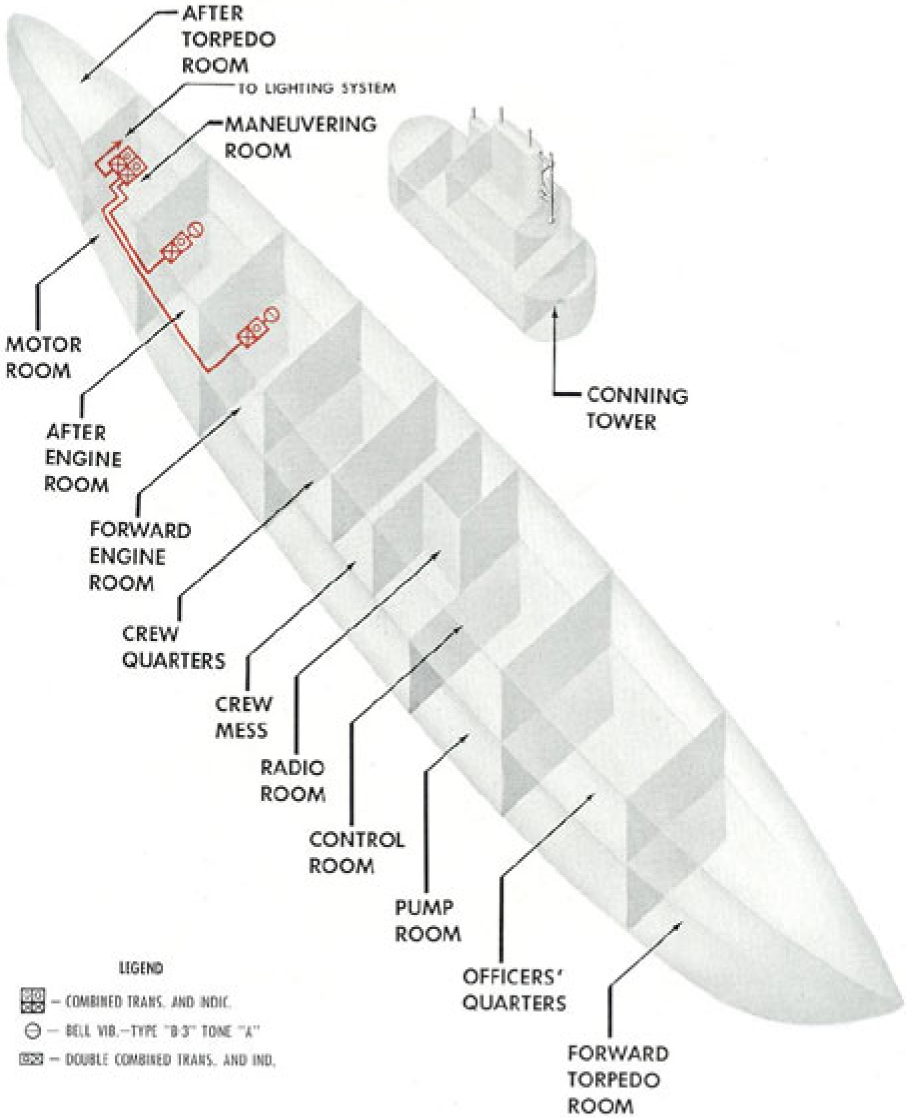

Figure 13-1. Schematic diagram of engine order indicator system.

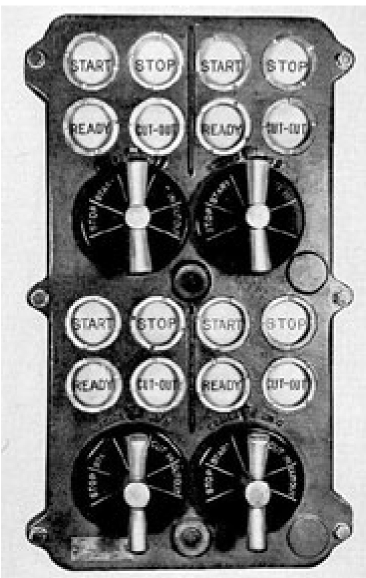

Figure 13-2. Engine order telegraph maneuvering room transmitter.

pressure, forcing the diaphragm upward against the tension of a coil spring and holding the contacts open. If the pressure drops below a set value, the diaphragm is forced downward by the spring tension and closes the contacts, energizing a light and bell circuit. The pressure at which the pressurestat functions may be varied by adjusting the spring tension. A pressurestat may be used either in oil or in water lines.

The thermostatic contact makers are installed in the circulating water lines leaving each main engine and the auxiliary engine. They perform the same function as

the pressurestat, but their contacts are closed by the effect of heat on a bimetallic strip.

The pressurestatic and thermostatic contact makers for each main engine are connected in parallel so that the operation of either one closes the circuit to a red indicator lamp and a horn at the engine control station, thus giving an alarm of an abnormal condition.

The pressurestats installed in the lubricating oil line between the reduction gears and main

Figure 13-3. Engine order indicator installed on engine gage board.

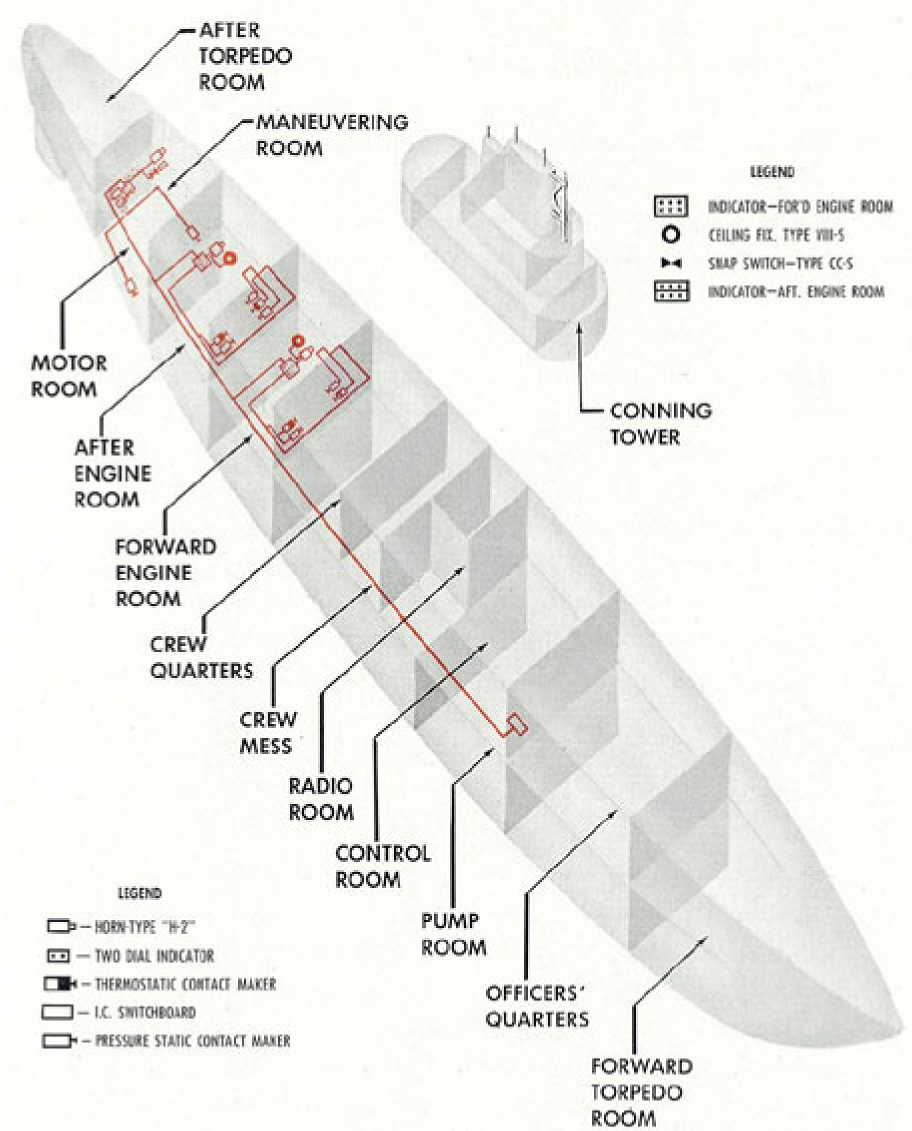

Figure 13-4. Schematic diagram of lubricating oil flow pressure) and engine circulating water (high temperature) alarm system.

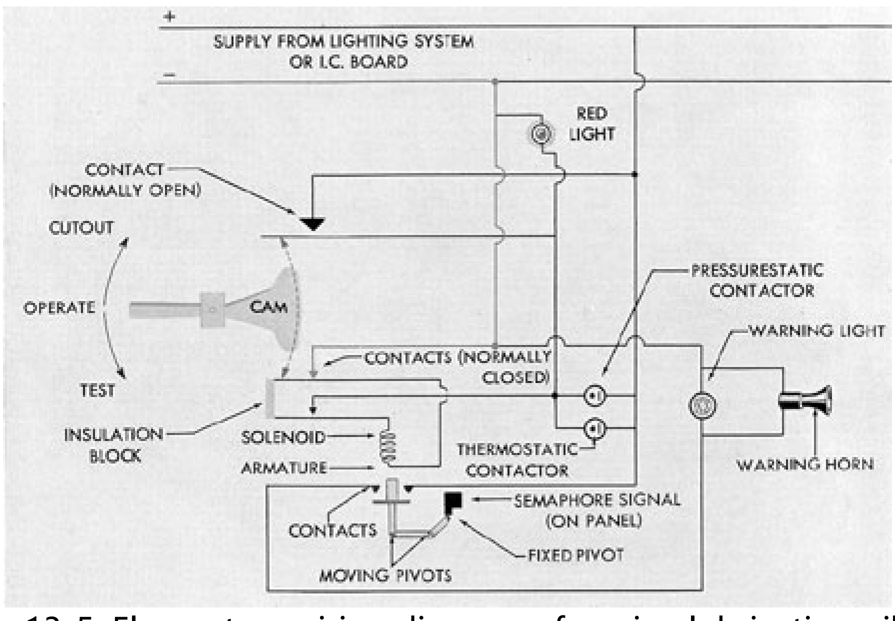

Figure 13-5. Elementary wiring diagram of engine lubricating oil flow pressure) and circulating water high temperature alarm system for one engine.

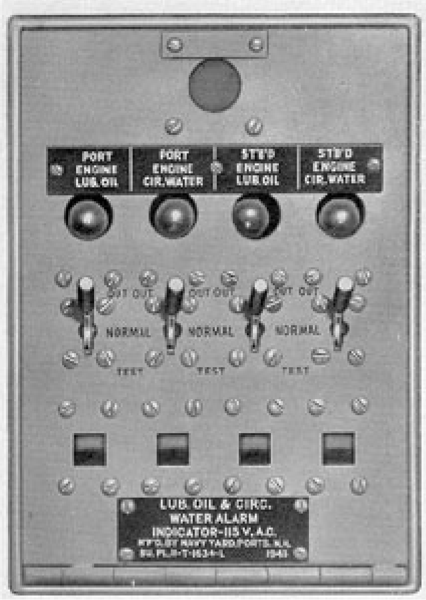

Figure 13-6. Lubricating oil (low pressure) and engine circulating water (high temperature) alarm panel.

motor bearings operate red indicator lamps and a horn in the maneuvering room.

A blue lamp at all indicator stations shows that the circuit is energized. Test cutout switches are also provided, by means of which the operation of the light and horn circuit may be tested.

Power for this system is taken either from the a.c. or d.c. bus (depending upon the type of installation) of the I.C. switchboard through a fused switch. The circuit designation is EC.

C. HULL OPENING AND MAIN BALLAST TANK INDICATOR SYSTEMS

13C1. Description. The hull opening and main ballast tank indicator systems are used to indicate, by means of lamps, the open or closed state of the openings in the hull.

Mechanically operated contact makers are used to operate a group of lamps located on a panel at the control stations. There are also mechanical indicators on the outside of the electrical contact box which provide a local indication of the position of a valve.

The group of panel lamps has colored glass covers of red or green mounted over each lamp. The lighting of these lamps indicates the dangerous position of the particular hull opening in red, and the safe position in green, both conditions being for

13C3. Main ballast tank indicator system (circuit TP). The main ballast tank indicator system has contact makers, including mechanical indicators, installed on the operating mechanism of each main ballast, safety, negative, and bow buoyancy tank vent valves. All flood valves and flood valve contact makers are omitted except those for the safety and negative tanks. Each contact maker is connected through a separate 3-ampere fuse to operate the 2 lamps in parallel for each of the indicator openings.

Red lights show flood valves actually closed tight and vent valves not completely closed. Green lights show vent valves that are actually closed tight and flood valves completely open.

the submerged condition. A dimmer for all lights is mounted on the after end of the indicator panel.

13C2. Hull opening indicator system (circuit TR). The hull opening indicator system has contact makers, including mechanical indicators, installed on the operating mechanism of each hatch, outboard ventilation, engine induction and exhaust valve. Each of these contact makers is connected through a separate 3-ampere fuse to operate the 2 lamps (in parallel) for each of the indicator openings.

An additional 10-dial indicator in each engine room is connected to show the position of the engine exhaust valves and the ventilation valves.

On all indicators, red lights show hatches, doors, engine valves, and hull ventilation valves not completely closed. Green lights show hatches actually dogged tight.

Power for the hull opening indicator system is obtained from the 8-volt secondary of either of two 120/8-volt transformers, depending on the position of the unfused switch on the I.C. switchboard. The common terminals of this switch feed the circuit through a set of 15-ampere fuses.

Lamps and their fuses in the control room and engine rooms may be identified by numbers engraved on the panels.

Power for the main ballast indicator system is obtained from the 8-volt secondary of either of two 120/8-volt transformers, depending upon the position of the fused primary switches for each transformer and the position of an unfused switch connected to the secondaries of the transformers. Power is taken from this switch through a pair of 10-ampere fuses on the I.C. switchboard.

13C4. Maintenance. Lamps and fuses may be tested by means of a jumper wire with one end connected to the circuit terminal screw provided near the bottom of the fuse panel. The other end of the wire must be touched to the top of the fuse for the lamp being tested. If both lamps for that circuit light, the fuse may be tested by touching the jumper wire to the bottom of the fuse clip.

A check for the proper operation of all hull opening contactors and indicators, followed by any necessary adjustments, should be made at the end of every overhaul or upkeep period and every 2 weeks thereafter.

Ballast tank contactors and indicators on flood and vent valve operating gear should be checked at intervals not to exceed 6 weeks and preferably at the end of the upkeep period. All mechanical indicators on hull opening valves should be checked at the same time the electrical contactors are checked.

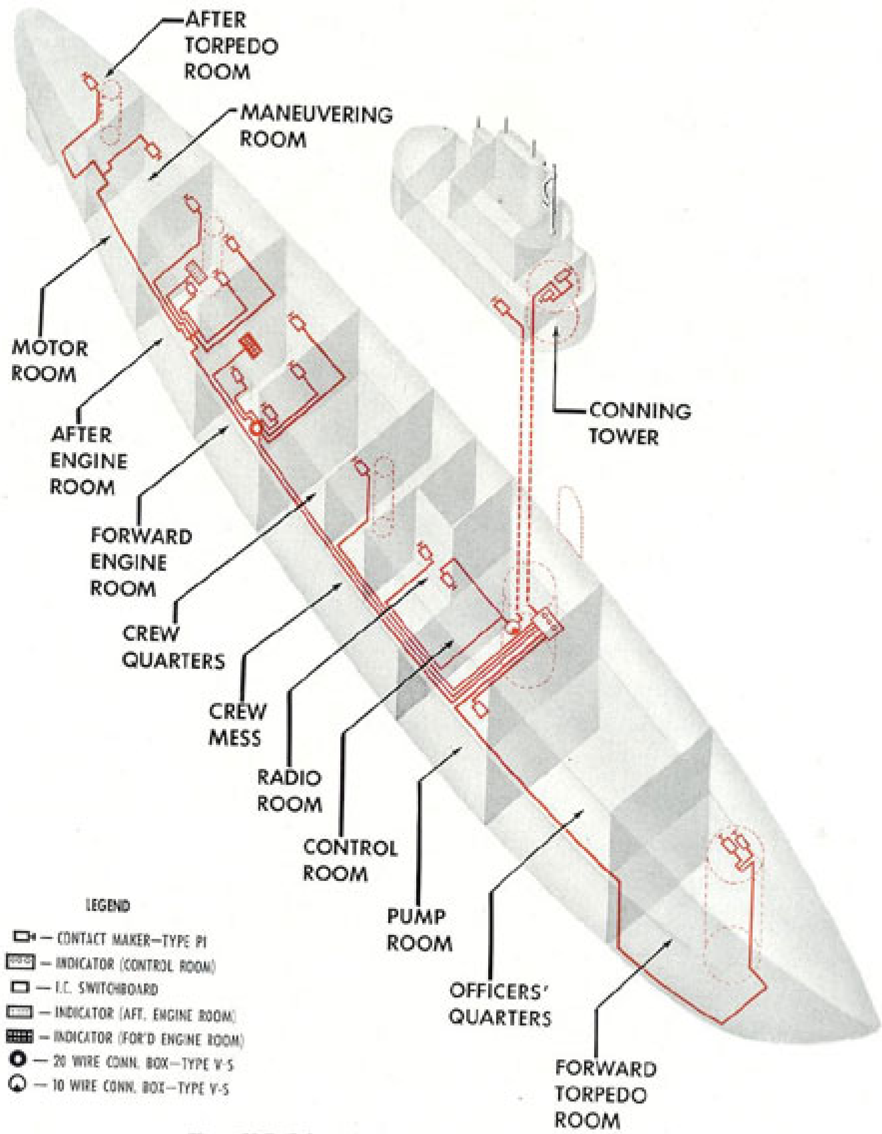

Figure 13-7. Schematic diagram of hull opening indicator system.

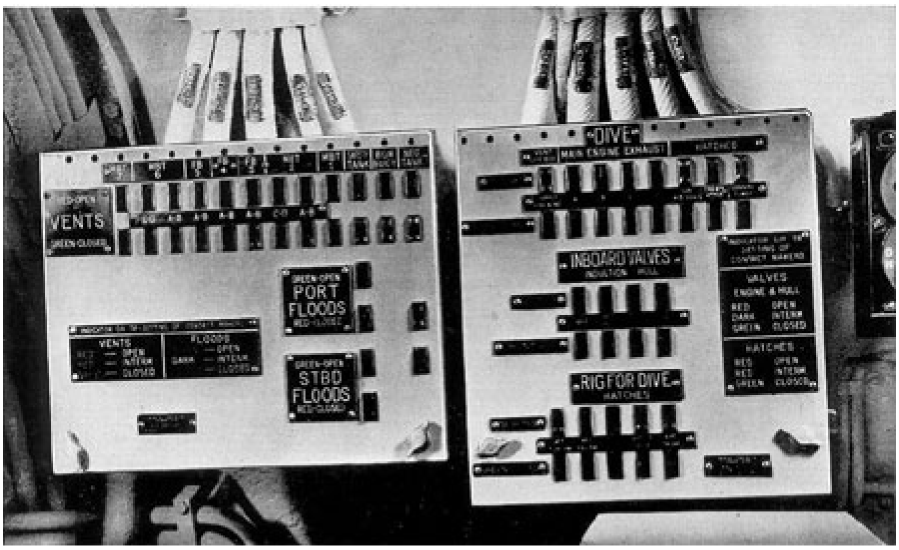

Figure 13-8. On board view of hull opening and main ballast tank indicators.

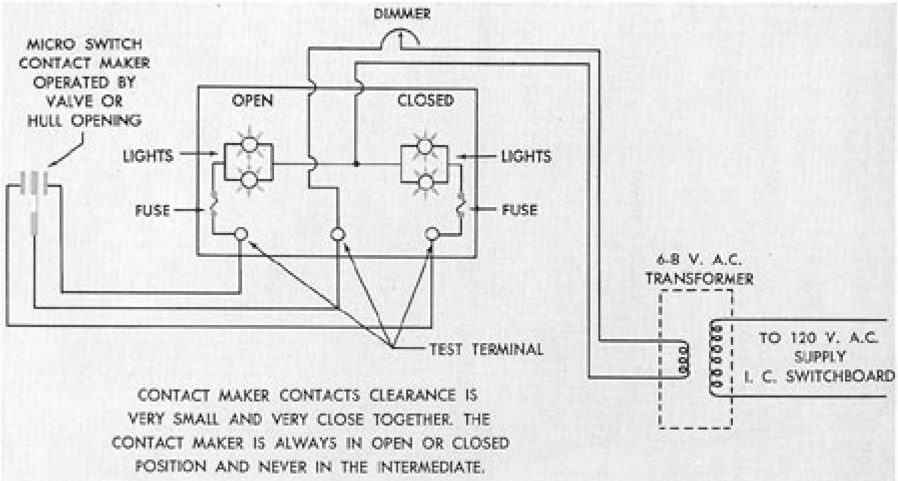

Figure 13-9. Simplified wiring diagram for one unit of hull opening and main ballast tank opening indicator systems.

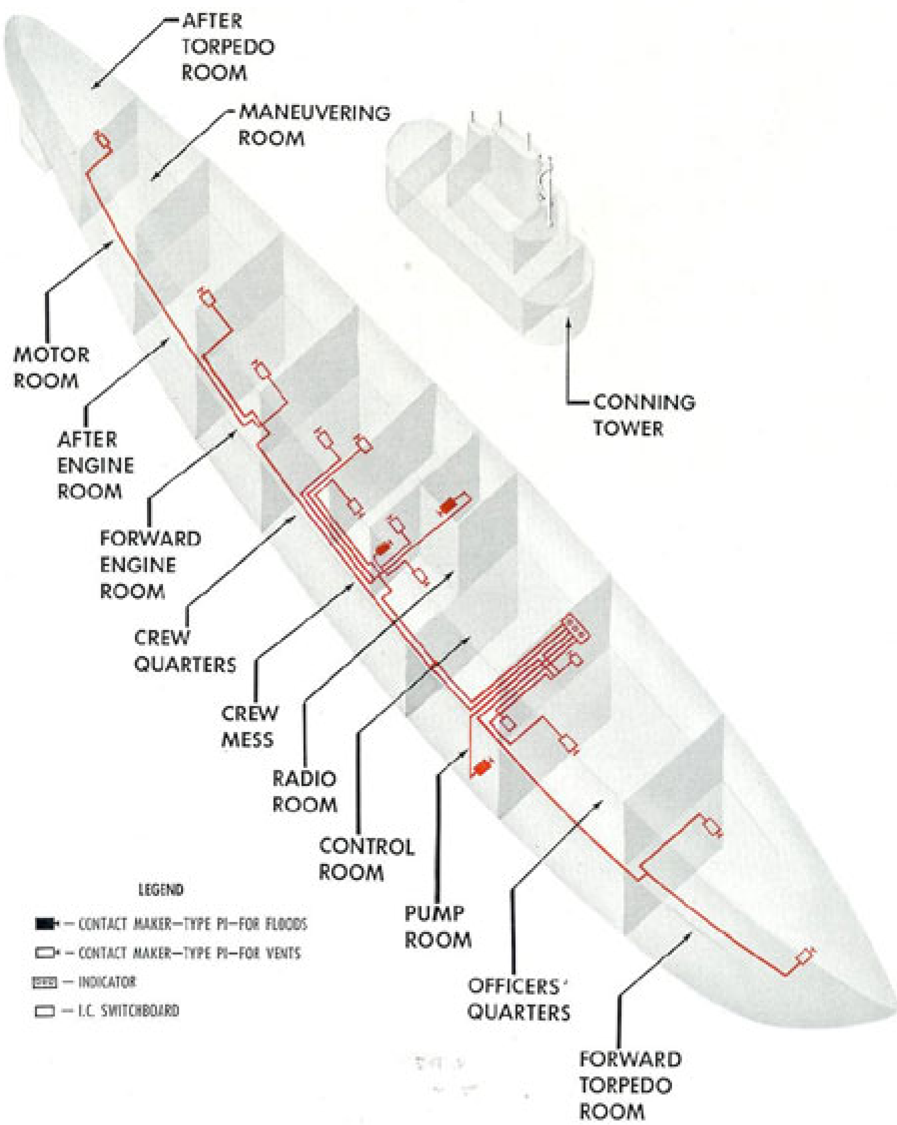

Figure 13-10. Schematic diagram of main ballast tank indicator system.

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should be given to checking for

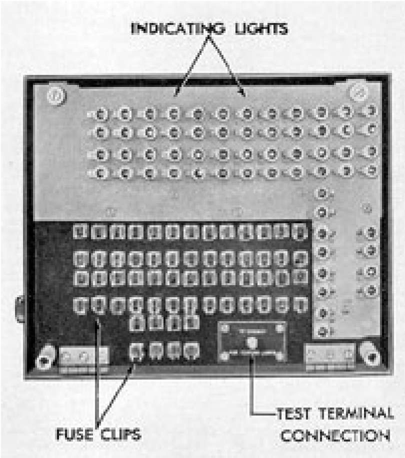

Figure 13-11. Main ballast tank indicator with cover open.

If contactors contain microswitches, check the switch pins for freedom of operation. Contactor rotating parts and contacts should be inspected for loose electrical connections and fittings, dirt, burrs, and presence of any foreign matter. Mechanical linkages should be inspected for freedom of action, adjustment, and presence of rust, corrosion, or any foreign material that might cause faulty operation. Special attention poorly fitting linkage pins, loose or missing cotter pins, and proper installation of linkages. When there is backlash in gears or wear in worms, readjustment is necessary.

The most serious results can be expected from improper operation either of the contactors on the hull openings which cannot be sight checked at rig for diving or of those valves that normally are not closed until after the first blast of the diving alarm. These valves include the hull ventilation valves, the main engine air induction valves, and the engine outboard exhaust valves.

13C6. Illumination of hull opening and main ballast tank indicators. The light from the indicators installed in the control room is reduced to a level satisfactory for preserving dark adaptation by means of rheostats installed in each system's supply lead. To prevent reduction of illumination in the instruments installed in the engine room, which are always under normal lighting, it has been necessary to install 2-contact split microswitches on openings whose position must be indicated in the control room. This results in full illumination of these indicators at all times. The power supply for the engine room indicators is not connected through the rheostats mentioned above. In other respects, the circuits resemble the simplified diagram shown in Figure 13-9.

D. RESISTANCE THERMOMETER AND PYROMETER SYSTEMS

13D1. Resistance thermometer that the electrical resistance of a

systems. a. Electrical distant reading thermometers are installed to read the temperatures of various parts of the propulsion system and auxiliary generator. They are of two different types: the Brown Instrument Company type, used to measure temperatures of the lubricating oil and bearing, and air temperatures of the propulsion motors and reduction gears; and the Weston continuous reading duplex type, used to measure the temperatures of the bearings and air in the generators and the lubricating oil and circulating water in the engines.

b. Brown resistance thermometer. The resistance thermometer is based on the principle metal changes with the temperature. In the Brown thermometer used on submarines the system consists of small coils of resistance wire called bulbs, located at the points to be measured, and an indicating unit. The indicating unit contains a selector switch, a power supply, fixed resistor units, and a galvanometer calibrated in degrees Fahrenheit.

The resistors in the instrument are arranged to form 3 sides of a Wheatstone bridge circuit with one of the bulbs selected by the switch forming the fourth side. Thus a change in resistance of the bulb causes an unbalance of the bridge and changes the reading of the galvanometer (see Figure 13-16).

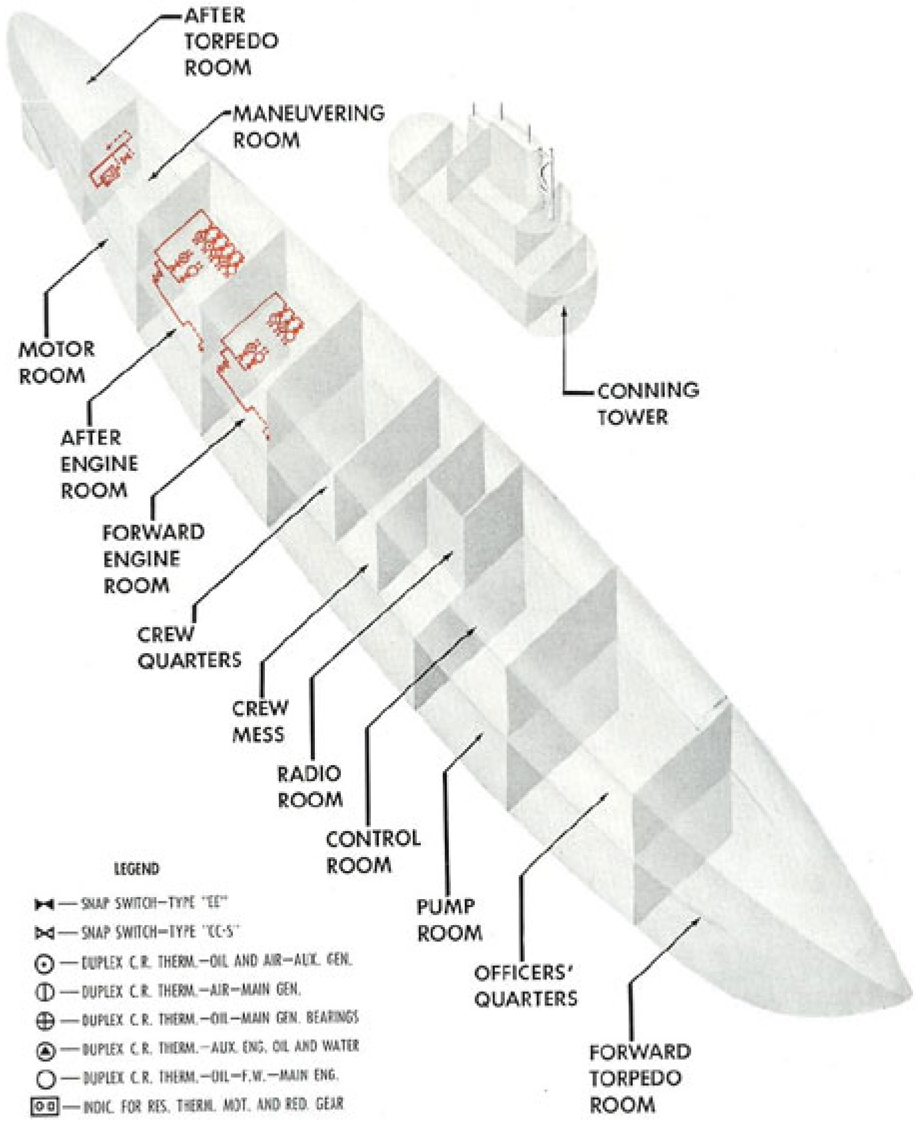

Figure 13-12. Schematic diagram of distant reading thermometer system.

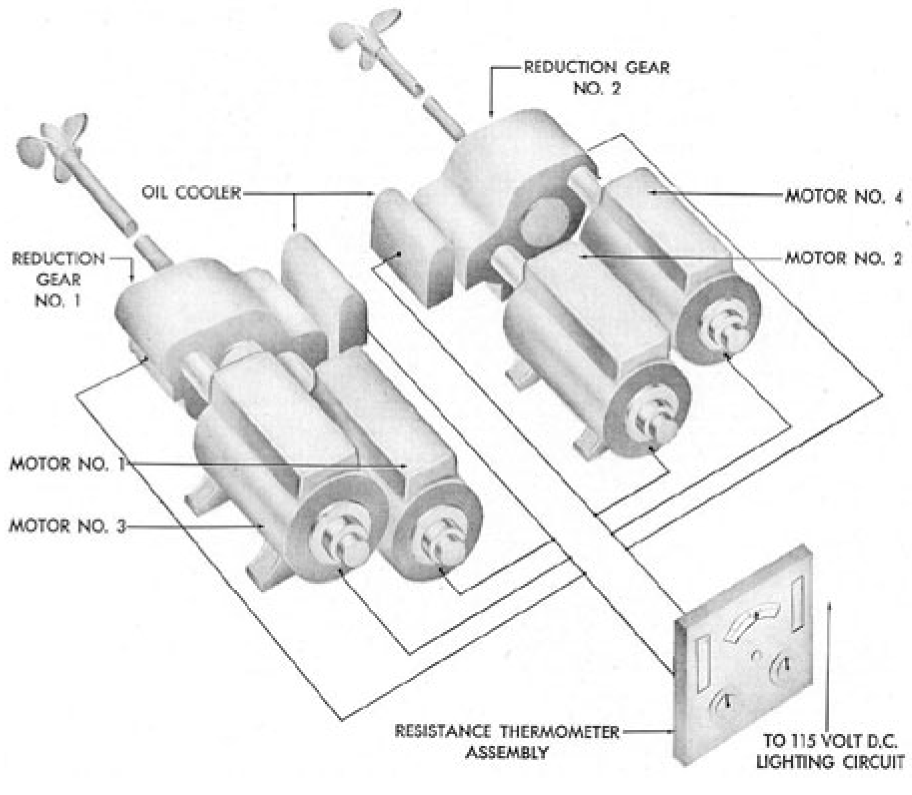

Figure 13-13. Schematic diagram of Brown distant reading thermometer system for main motors and reduction gears.

The power supply consists of a transformer and rectifier for the later vessels and a resistor and rheostat for dropping the voltage from the 115-volt d.c. lighting system for earlier vessels. In both types the final input to the instrument is approximately 8 volts d.c.

c. Weston duplex continuous reading thermometers. The Weston resistance thermometers used on submarines depend on the same principle as the Brown type, with one major difference: Instead of a simple Wheatstone bridge and galvanometer, a modified bridge and an instrument known as a ratiometer are used. The circuit is shown in Figure. 13-17. R_3 is made equal to R_4. Hence it can be seen that the current in the 2 coils C_1 and C_2 of the instrument will be the same when the resistance of R_1 equals the resistance of R_5. For any other resistance of R_1, more current will flow in one coil than in the other. In the instrument, the 2 coils are mounted on opposite sides of the pivot. A soft iron circular core threads through the coils. A permanent magnet yoke with 2 semicircular pole pieces almost surrounds the moving coils and core but it is slightly eccentric with respect to the pivot. This causes the air gap to be smaller at one side than the other. As currents flow in the 2 coils connected to produce torque in opposite directions, they move to such a position that their torques are equal. Since torque is determined by the product of the current in the coil and the magnetic flux across the air gap, the coil carrying the least current moves to a

point in the air gap having greater flux density, that is, toward the narrow gap. Since the position of the pointer depends on the ratio between 2 currents rather than on their absolute value, voltage fluctuations have no effect on the accuracy of the instruments. In the Weston thermometers, a separate movement is furnished for each temperature point, 2 being combined into a single duplex instrument.

Figure 13-14. Brown distant reading resistance thermometer indicator and switch panel.

As with the Brown type instruments, the Weston type also may be either d.c. or a.c., and the series resistor or

transformer and rectifier are incorporated in the instrument case.

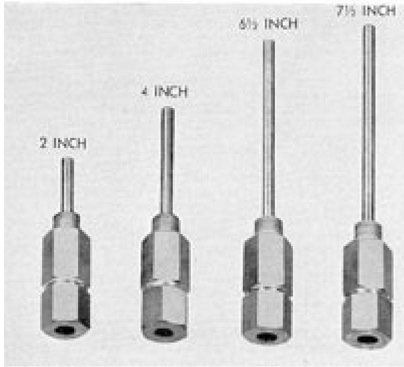

Figure 13-15. Weston resistance thermometer bulbs.


Figure 13-16. Brown resistance thermometer bulb.

13D2. Brown indicating pyrometers. The temperature of the exhaust gas from a cylinder of any diesel engine is a reliable indication of the load on that particular cylinder.

The exhaust gas temperatures of each cylinder are obtained with a Brown indicating pyrometer which makes use of the thermoelectric principle of dissimilar metals: An electromotive force is generated in a circuit of 2 wires of different metals when the 2 junctions of those wires are at different temperatures. This electromotive force varies in magnitude with the difference in temperature between the 2 junctions. The hot junction is exposed to the temperature of the exhaust gas, and the cold junction is located at a galvanometer through which the circuit is closed. This galvanometer is the indicator and is graduated in degrees of temperature corresponding to the voltage generated. Because the generated electromotive force is zero when the 2 junctions are at the same temperature, the galvanometer is adjusted to indicate its own, or cold junction, temperature when the circuit is open, or in the OFF position. The galvanometer automatically varies its pointer position with changes in the temperature at the hot junction.

One of the 2 thermocouple wires is made of pure iron; the other is made of constanten, a nickel-copper alloy. The wires are

welded at the tip of the thermocouple and mounted in a closed-end protecting tube of pure nickel. The protecting tube is fitted with a terminal head in which the connections are made between the extension leads and the thermocouple wires.

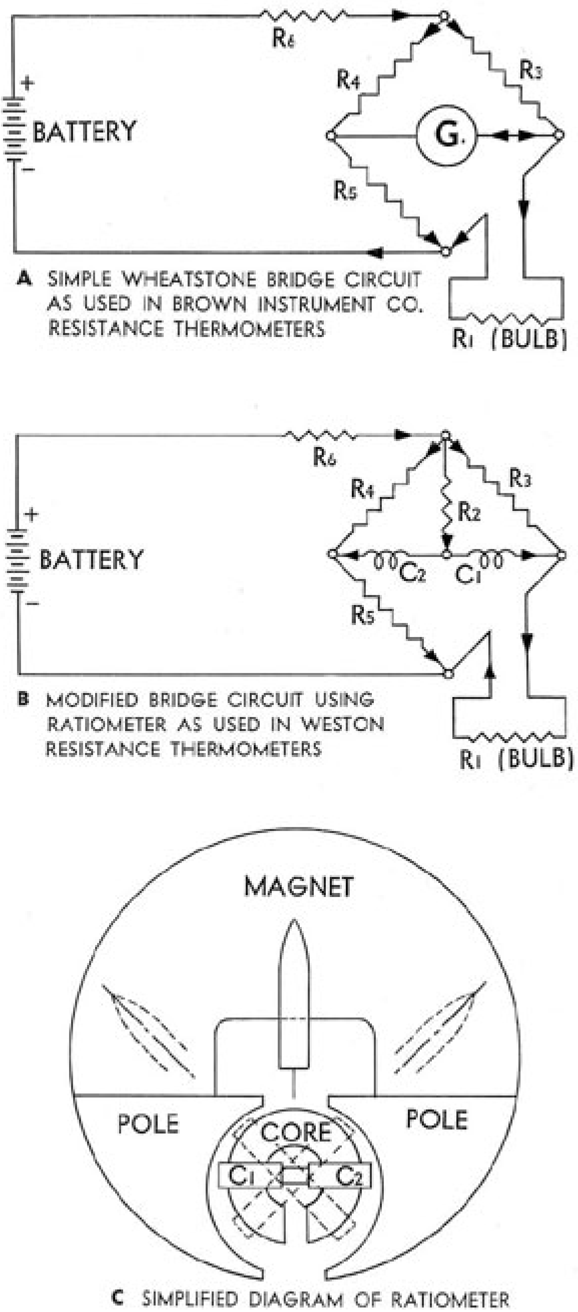

Figure 13-17. Electrical resistance thermometers.

temperature of the combined exhaust gas from all cylinders can

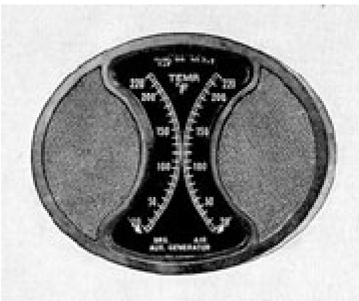

Figure 13-18. Duplex constant reading resistance thermometer gage.

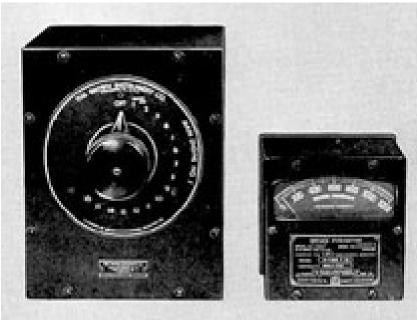

Figure 13-19. Brown pyrometer indicator and rotary switch for main engine exhaust temperatures.

The indicating mechanism is essentially a millivoltmeter, calibrated in degrees of temperature corresponding to the temperature-emf relationship of the iron-constanten thermocouple. The galvanometer is, and functions as, a common direct current instrument except for the fact that the adjusting screw is used for ambient temperature setting instead of zero setting.

To obtain the best indication of diesel engine temperatures, it is necessary to place a thermocouple tip in the exhaust port of each cylinder. Some engines also use a thermocouple at a point in the exhaust pipe system where the be measured. This point is called the common temperature.

The Brown pyrometer system includes a multipoint switch through which the individual thermocouples are connected to the indicator.

All connections between thermocouples and the instrument are made with the wires supplied for this purpose: the iron wire being used for the positive lead, and constanten wire for the negative lead. These 2 wires are of the same material as the thermocouple and cause the cold junction to be extended from the thermocouple terminals back to the indicator. No other types of wire are used for this purpose.

Resistors are provided in the system and are used for adjusting the resistance of the external leads to a standard value. The galvanometer of this instrument is calibrated for a 15ohm external resistance. The resistor connections simply increase the total resistance of the extension leads to 15 ohms, and this amount should not be exceeded.

The resistors do not compensate for ambient temperature changes.

Figure 13-20 Pyrometer unit as installed in engine.

13D3. Maintenance. Frequent inspections must be made to insure that all connections are tight and free from corrosion. As small voltage values are used in these circuits, the accuracy of the instrument depends on perfect contact.

Thermocouples and thermometers usually cannot be repaired if faulty, but must be replaced. It is essential, therefore, that a full allowance of spare thermocouples and thermometers be carried aboard at all times.

E. HYDROGEN DETECTOR SYSTEM

13E1. Description. There are two types of hydrogen detectors in service: type N.H.D., manufactured by the Cities Service Company, and type M.S.A., manufactured by the Mine Safety Appliance Company. The function of the detectors is to take a sample of exhaust air continuously from the batteries and indicate the percentage of hydrogen concentration in the battery ventilation ducts.

The operation of both types of detectors is based on the principle of a balanced Wheatstone bridge circuit. The air sample is drawn, by means of a motor-driven pump, across one leg of the balanced circuit where it is caused to burn with an intensity dependent upon the amount of hydrogen present. The heat created heats that leg and increases its resistance, thereby creating an electrical unbalance in the entire circuit. The meter connected across the bridge circuit then shows a deflection, on a properly divided scale, that is directly proportional to the percentage of hydrogen present in the air sample.

In addition to the meter indication, the M.S.A. type contains a white light connected in the circuit, indicating normal operation as long as the hydrogen content is below 3 percent. When the motor pointer indicates 3 percent on the scale, a circuit to a red warning light is closed. This red warning light will remain ON until it is manually reset. Both meter and light indications are transmitted to repeater instruments in the maneuvering room.

The type N.H.D. detector is supplied with 115-volt to 120-volt alternating current directly from the a.c. bus of the I.C. switchboard. This system uses a rectifier to convert the alternating current into direct current for the bridge circuit.

The M.S.A. type detector is supplied with 120-volt direct current from the lighting feeder.

Detailed descriptions of these systems and specific instructions for maintenance, repair, and adjustments may be found in the manufacturer's instruction book pertaining to the particular type of installation.

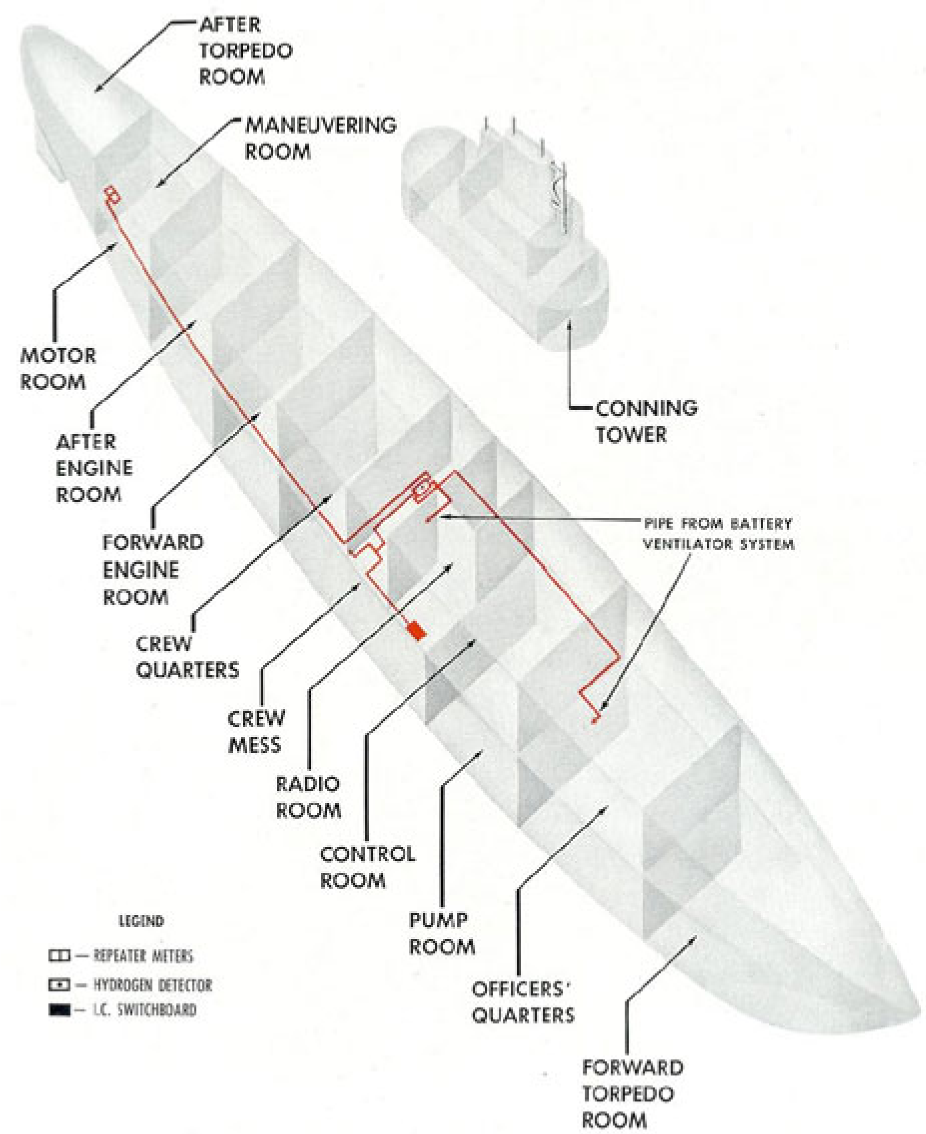

Figure 13-21. Schematic diagram of hydrogen detector system.

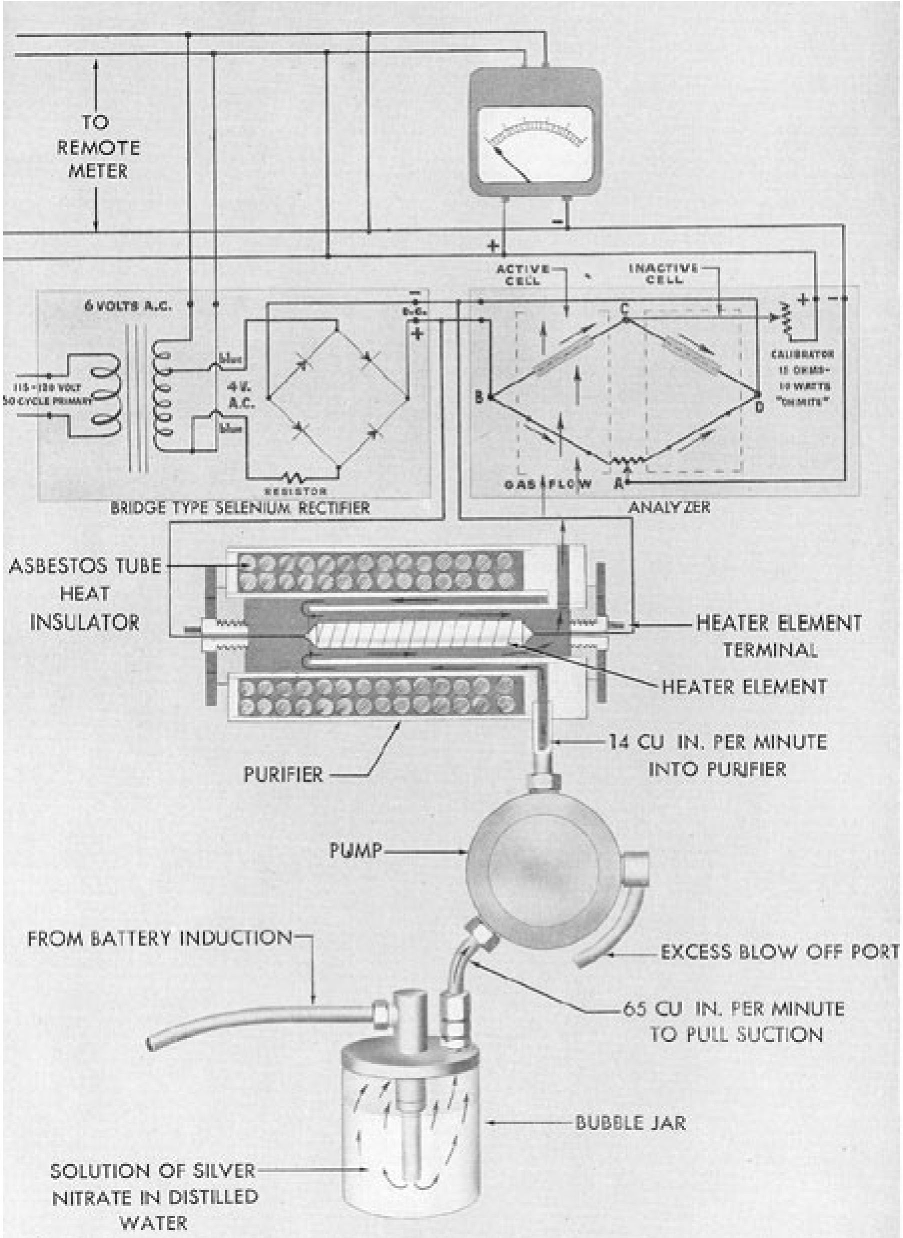

Figure 13-22. Schematic diagram of Cities Service type hydrogen defector.

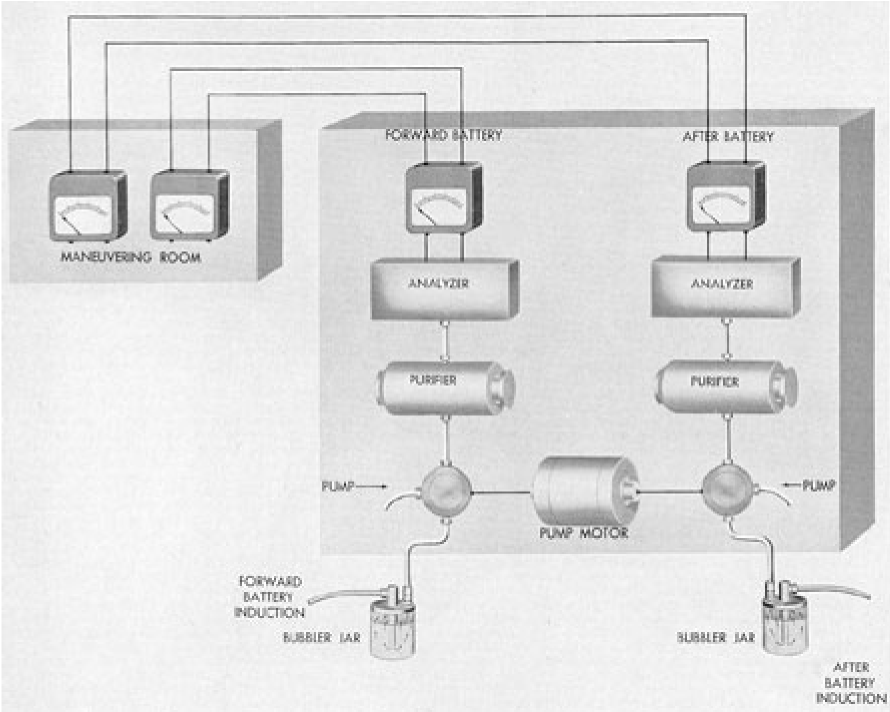

Figure 13-23. Arrangement of units in Cities Service type hydrogen detector.

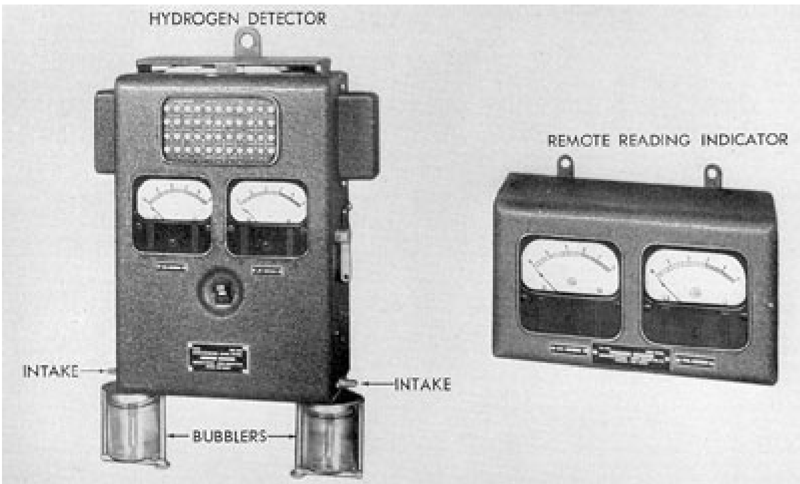

Figure 13-24. Cities Service type hydrogen detector system, master indicator and remote indicator.

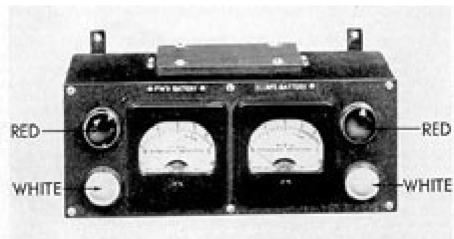

Figure 13-25. M.S.A. type hydrogen detector remote indicator.

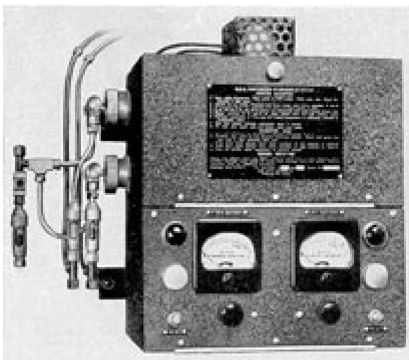

Figure 13-27. M.S.A. type hydrogen detector.

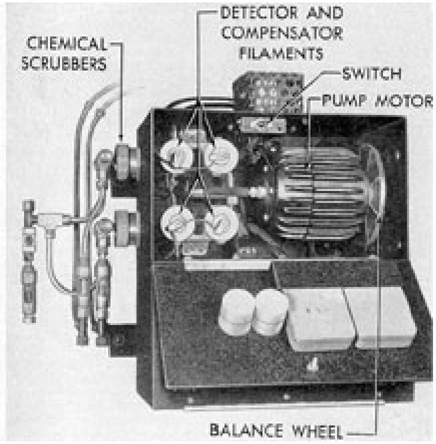

Figure 13-26. M.S.A. type hydrogen detector with door open.

14
FIRE CONTROL AND GUNNERY SYSTEMS

A. TORPEDO FIRE CONTROL SYSTEM

14A7. Description. The torpedo fire control system employs several electrical devices which assist in solving fire control problems and firing the torpedo tubes. The devices that perform these functions are the torpedo data computer, the gyro angle indicator regulators, and the torpedo ready and firing light systems.

The torpedo data computer is located in the conning tower and is energized by circuit GA1, having 115-volt alternating current, and circuit 17GA1, having 115-volt direct current, through individual double pole, single throw, fused switches on the I.C. switchboard.

The gyro angle indicator regulators for automatically setting the gyro angles on the torpedoes in the tubes are located at the forward and after tube nests and are controlled by separate fire control circuits from the torpedo data computer. The regulators are supplied with 115-volt direct current through circuit 17GA3 which is energized through a double pole, single throw switch on the forward auxiliary power switchboard in the control room, and circuit 17GA4 which employs a similar switch on the after auxiliary power switchboard located in the maneuvering room. Sixty-ampere fuses, in special fuse boxes, are included in each circuit.

The following circuits are provided in addition to those mentioned above:

1. A Pitometer log repeater circuit to the torpedo data computer from a rotary transfer switch on the action cutout switchboard.

2. A gyrocompass repeater circuit to the torpedo data computer from the gyrocompass repeater panel.

14A2. Operation. Detailed operating procedures are given in Bureau of Ordnance publications and the manufacturer's instruction pamphlets.

B. TORPEDO READY LIGHT, TORPEDO FIRING, AND BATTLE ORDER SYSTEMS

14B1. General description. The switchboard through a fused

torpedo ready light and torpedo firing systems perform several important functions: They provide a means 1) of informing the fire control party when the tube is ready to fire, 2) of directing the tube crew to stand by a tube to fire, 3) of firing the torpedoes remotely from the conning tower and simultaneously indicating to the tube crew by means of an audible and visual signal that the tube has been fired, and 4) of indicating by a visual signal in the conning tower that the tube has fired. They also indicate, by means of a visual signal to the fire control party in the conning tower, that the gyro angle indicator regulators are matched.

14B2. Torpedo ready light and battle order system. This system, circuit 6R, is energized from the 120-volt direct current bus on the I.C. double pole, single throw supply switch labeled 6R. Forward and after transmitters in the conning tower are used to transmit torpedo orders to an indicator at each tube nest. When power is turned on in the conning tower, the GYRO SPINDLE and READY pilot lights in the transmitter, the READY AT TUBE, and the STANDBY pilot lights in the corresponding indicator in the torpedo room are lighted. When the gyro retraction spindle switch contacts are closed, an amber GYRO SPINDLE IN light in the indicator in the conning tower for that tube is lighted. When the tube interlock switch contacts are closed, the amber READY AT TUBE light for that tube in the indicator in the torpedo room is lighted. When the operator turns the indicator switch for that tube, it lights a green READY light for the tube in the transmitter in the

Figure 14-1. DIAGRAM FLEET TYPE SUBMARINE READY LIGHT AN FIRING CIRCUITS, FOR TORPEDO TUBE 7 ONLY.

conning tower. When the gyro mechanism of the tube nest is matched upon closing the manual contact of the gyro setting mechanism contact maker, a red ANGLE SET light in the transmitter in the conning tower is lighted. When a particular tube standby switch in the conning tower is turned to STANDBY at the transmitter, the corresponding green STANDBY light for that tube in the indicator in the torpedo room is lighted. When the firing contact maker is pressed, the tube is

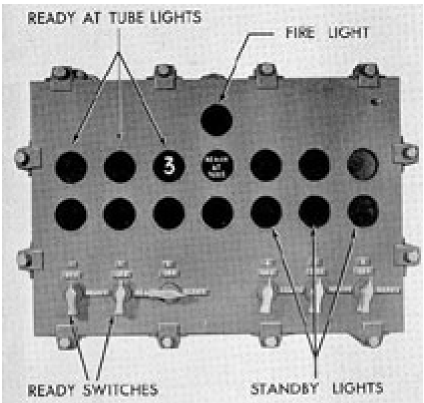

Figure 14-3. Torpedo room ready light and ready switch panel.

fired through operation of the pilot valve solenoid; a red FIRE light in the indicator is lighted and a buzzer is operated at the tube nest.

14B3. Torpedo firing system. The torpedo firing system, circuit 6PA, is energized from the 120-volt direct current bus on the I.C. switchboard through a fused double pole, single throw supply switch labeled 6PA.

Separate fixed and portable contact makers or firing keys, for independently controlling the forward and after groups of firing solenoids, are located at the torpedo ready light and firing panels in the conning tower. A key mounted on the gyro angle regulator indicators operates a light on this panel to show that the regulator is matched.

Firing circuits are interrupted through

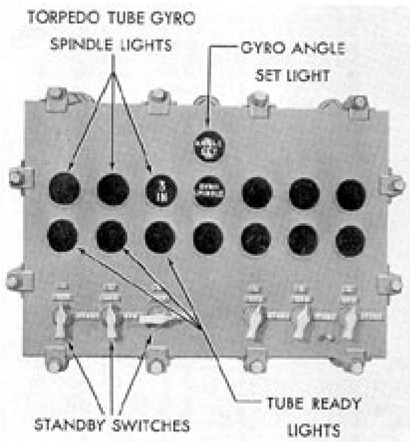

Figure 14-2. Conning tower torpedo firing panel.

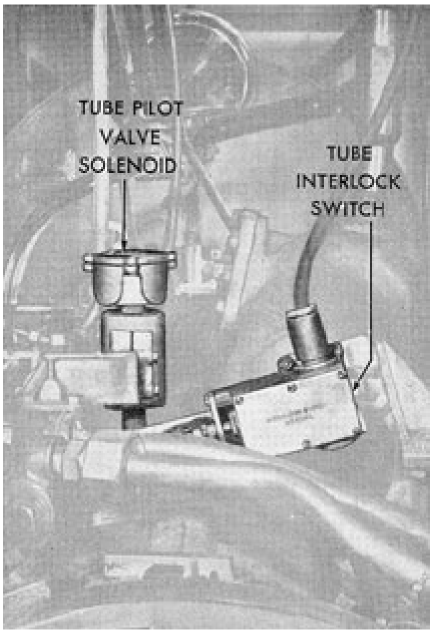

Figure 14-4. Torpedo tube interlock switch and pilot valve solenoid.

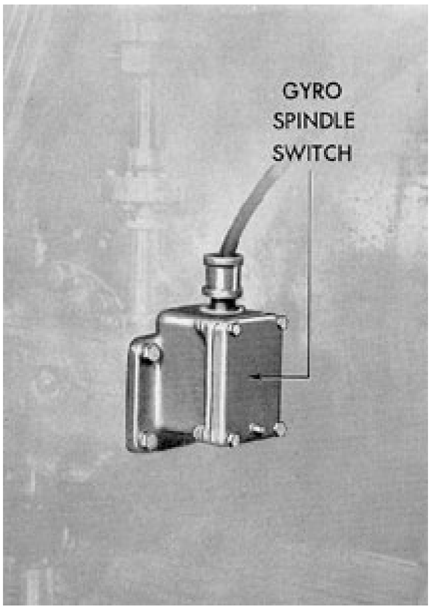

Figure 14-5. Spindle switch on torpedo tube gyro setting mechanism.

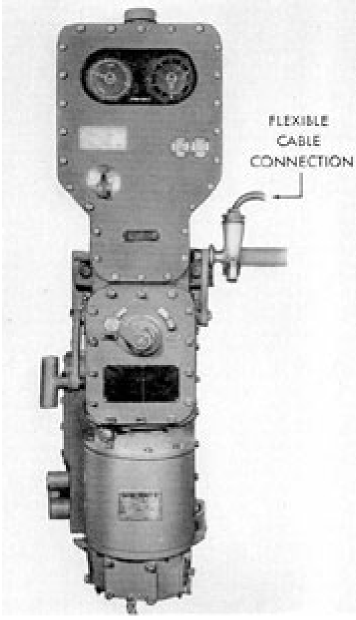

Figure 14-6. Gyro angle regulating indicator with right handgrip turned to show trigger switch.

switches on the torpedo ready light and firing panel and through local interlock switches at each torpedo-tube as shown in the wiring diagram, Figure 14-1, which is complete for one tube only.

14B4. Operation. A full description of the method of operation is given in Bureau of Ordnance publications and in the manufacturer's instruction pamphlets. They should be consulted frequently.

C. TARGET DESIGNATION SYSTEM

14C1. General. The target designation system is used for the purpose of transmitting and indicating the bearing of the target from the bridge or radar to the torpedo data computer (TDC) and the 2 plotting stations. It is a simple selsyn-operated system using manually operated bearing transmitters on the bridge and an automatic transmitter coupled to the train mechanism of the radar. The indicators at the plotting stations show the true as well as the relative bearing. A buzzer system with hand contactors at the control room indicate the true as well as the relative bearing by means of a second dial which receives from the gyro system and indicates own course. The type used at the TDC shows the relative bearing only, but utilizes 2 dials, coarse and fine, so that increased accuracy is gained. An additional indicator showing both the true and the relative bearing is located at the radar to aid in coaching the operator of this latter instrument on the bearing of the target. This is a coarse reading instrument, its dial being graduated in 5-degree increments. Selector switches are

transmitting stations and buzzers at the plotting stations, radar, and TDC is provided for indicating when the transmitter is on the bearing of the target. A set of rotary cutout switches is located at the TDC so that the operator may shift the bearing indicators to the transmitter that is to furnish the bearings. The circuit designation is GT. It is energized from the a.c. bus by a fused switch on the I.C. switchboard. Own course input for the indicators that show the true as well as the relative bearing is obtained from the gyrocompass repeater panel through a rotary switch.

14C2. Target bearing transmitter. This instrument consists of 2 permanently mounted peloruses on the bridge. One is located at each end of the bridge. Each pelorus has a pair of watertight and pressure-proof binoculars of the high light transmission type. An illuminating system is built into them to make the cross wires visible when the instrument is used at night. The pelorus can be rotated through 360 degrees in azimuth and is equipped with a scale so that the operator may read the bearing at which the instrument is set. A selsyn generator inside the pressure-proof case of the instrument transmits the bearing of the target when the pelorus is pointed at it. The hand contactor for the buzzer system is built into one of the training handles.

14C3. Target bearing indicators. These instruments, when energized and connected to a transmitter, indicate the provided at the TDC so that various indicators may be switched to the transmitter that is to furnish the bearing.

14C4. Operation. Full instructions for the operation of this system are contained in publications of the Gunnery Department of the Submarine School and in manufacturer's instruction books.

14C5. Maintenance. Maintenance of the target designation system is identical with that of any other system containing selsyn instruments. Special care must be taken in sealing the target bearing transmitters to insure that the watertight joints and the cable packing glands are carefully made up in order to prevent flooding and consequent disabling of the instrument.

14C6. New installations. The latest design installations have, in addition to the units described above, additional transmitters operated by the sound gear and the periscopes for the transmission of both bearing and range to the stations equipped with indicators. In addition, an improved model of the target bearing transmitter is provided with an own course dial energized from the gyro repeater panel so that the true as well as the relative bearing may be read at the instrument. The ship's plans should be consulted for details.

A center section containing three 2-dial bearing indicators, and a range indicator with selector switches so that the bearing may be received from the target bearing transmitters on the bridge, the periscopes, radar, or the sonar

bearing as transmitted by the target bearing transmitters. Their construction is similar to any other simple selsyn indicating device. The type installed at the plotting stations in the conning tower and in the system has been added to the TDC. A range

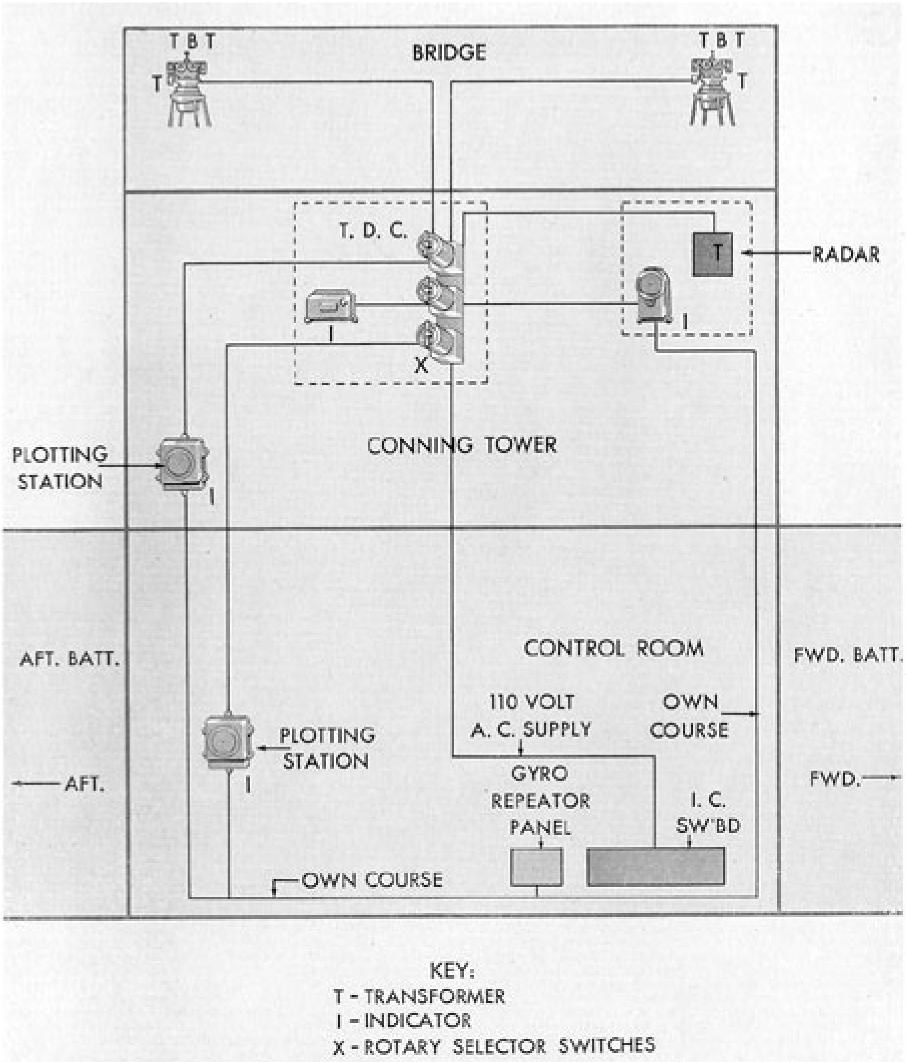

Figure 14-7. Schematic diagram of target designation system.

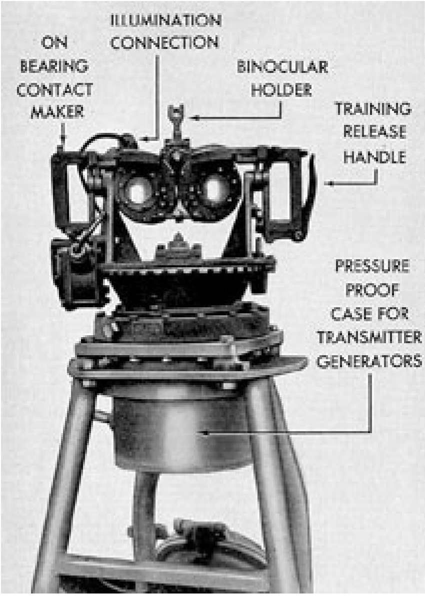

Figure 14-8. Target bearing transmitter, Mark 8.

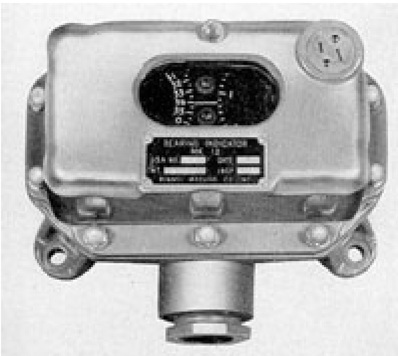

Figure 14-9. Target bearing indicator, type installed at TDC.

Figure 14-10. Target bearing indicator, type installed At plotting stations.

Figure 14-11. Target bearing indicator, type installed at radar.

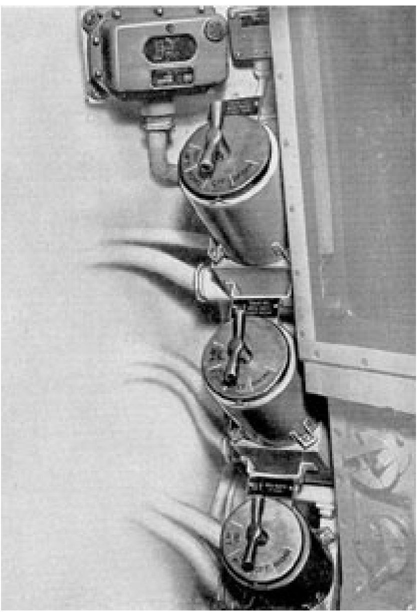

Figure 14-13. True bearing and range indicator at plotting stations, newest installations.

indicator for receiving range either from the radar or from the sonar system is also provided. Auxiliary

Figure 14-12. Bearing Indicator and bearing indicator selector switches installed at TDC.

pointers, mechanically controlled by movement of the TDC input dials for bearing and range, are provided so that the indicated values of relative bearing and range may be introduced into the TDC simply by matching the pointers with the value indicated.

D. TORPEDO BATTERY CHARGING AND HYDROGEN BURNING SYSTEMS

14D1. Torpedo battery charging system. The battery charging circuits are brought to indicating panels and receptacles located at the racks and the tubes. The circuits take main battery voltage, through a rheostat, to outlets from which connections may be made by portable cables to charge torpedo batteries either when the torpedoes are in the tubes or when they are in the racks. Ammeters are provided in the charging circuits.

The arrangement of outlets for the charging circuits varies from ship to ship, but in general, individual units are identical.

Supply switches are usually located at the forward torpedo room auxiliary power panel and the maneuvering room auxiliary power distribution panel.

14D2. Torpedo hydrogen burning system. The battery compartment of each torpedo is equipped with 3 hydrogen burners located directly under the inspection plates. Each burner is constructed of a small coil of resistance wire mounted in a copper mesh casing. The coil of resistance wire reaches a temperature sufficiently high to ignite any hydrogen gas that may be generated by the batteries.

Power supply to the burning units is provided by control panels located in each torpedo room. They have a sufficient number of outlets to accommodate all torpedoes in the tubes and on the racks. Each burner is supplied with a.c. from the I.C. switchboard through a transformer in the control panel. Each outlet is controlled by a switch, and the current to each burner can be read on an ammeter through a selector switch. A line level compensator is provided in the panel to keep the current to each torpedo at 4.75 amperes. Fine adjustments for individual circuits may be made by adjusting a resistor provided for each outlet.

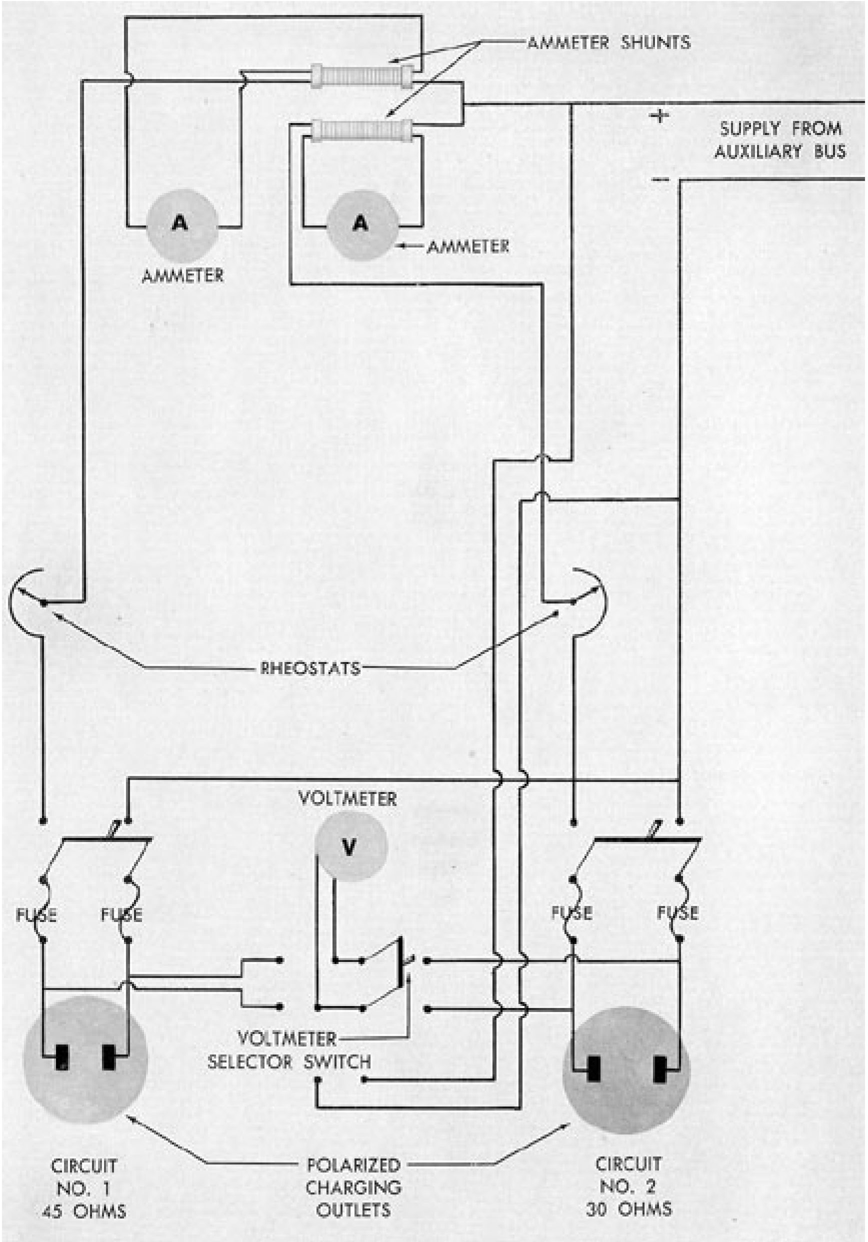

Figure 14-14. Schematic diagram of torpedo battery charging controller.

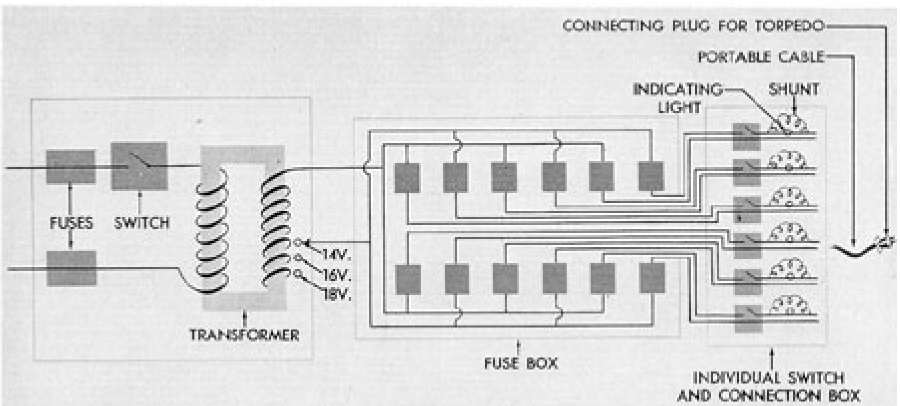

Figure 14-15. Schematic diagram of hydrogen burning circuit.

Figure 14-16. Electric torpedo battery charging panel.

Figure 14-17. Electric torpedo hydrogen burning circuit controller.

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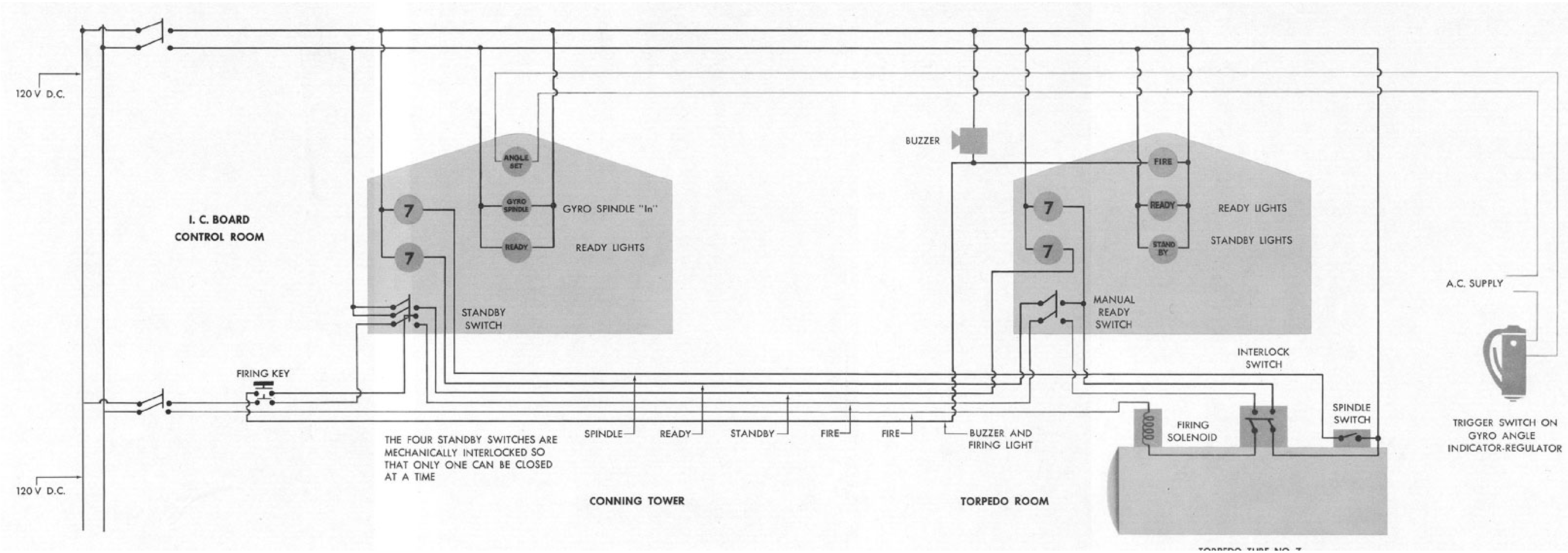
Figure 14-1. DIAGRAM FLEET TYPE SUBMARINE READY LIGHT AN FIRING CIRCUITS, FOR TORPEDO TUBE 7 ONLY.

Sub Elec. Home Page



Version 1.10, 22 Oct 04

15
UNDERWATER SOUND SYSTEM

A. CIRCUIT AND COMPONENTS

15A1. Description. The underwater sound system consists of directional hydrophones, supersonic high gain receiver amplifiers, transmitters, range indicators and necessary polarizers, rectifiers, motor generator sets, training motors and indicators, and the necessary control gear. The circuit letters are SRT, S1RC, and S2RC. The 120-volt direct-current power is supplied directly from the forward battery through 2 separately fused connection boxes, one tapped into the jumper between cells 33 and 34, and the other into the jumper between cells 93 and 94. This circuit is brought to a polarized single outlet receptacle in the after end, port side, of the forward torpedo room near the amplifiers. Power is taken through a line filter supplied with the rest of the equipment, before being fed into the amplifier, in order to reduce noises that might otherwise be introduced from the power supply.

The supersonic system obtains alternating current from the ship's a.c. supply through fuses and disconnect switches in the radio room. The supply to the conning tower equipment is taken through two 15-ampere fuses and a double pole, single throw, snap switch.

Direct current is also taken from the auxiliary power distribution panel in the forward torpedo room through four 30-ampere fuses; 2 fuses feeding the motor controller panel for the QB training MG set, and the other 2 feeding the motor controller for the QC-JK training MG set.

Installations vary greatly and the ship's plans should be consulted for details.

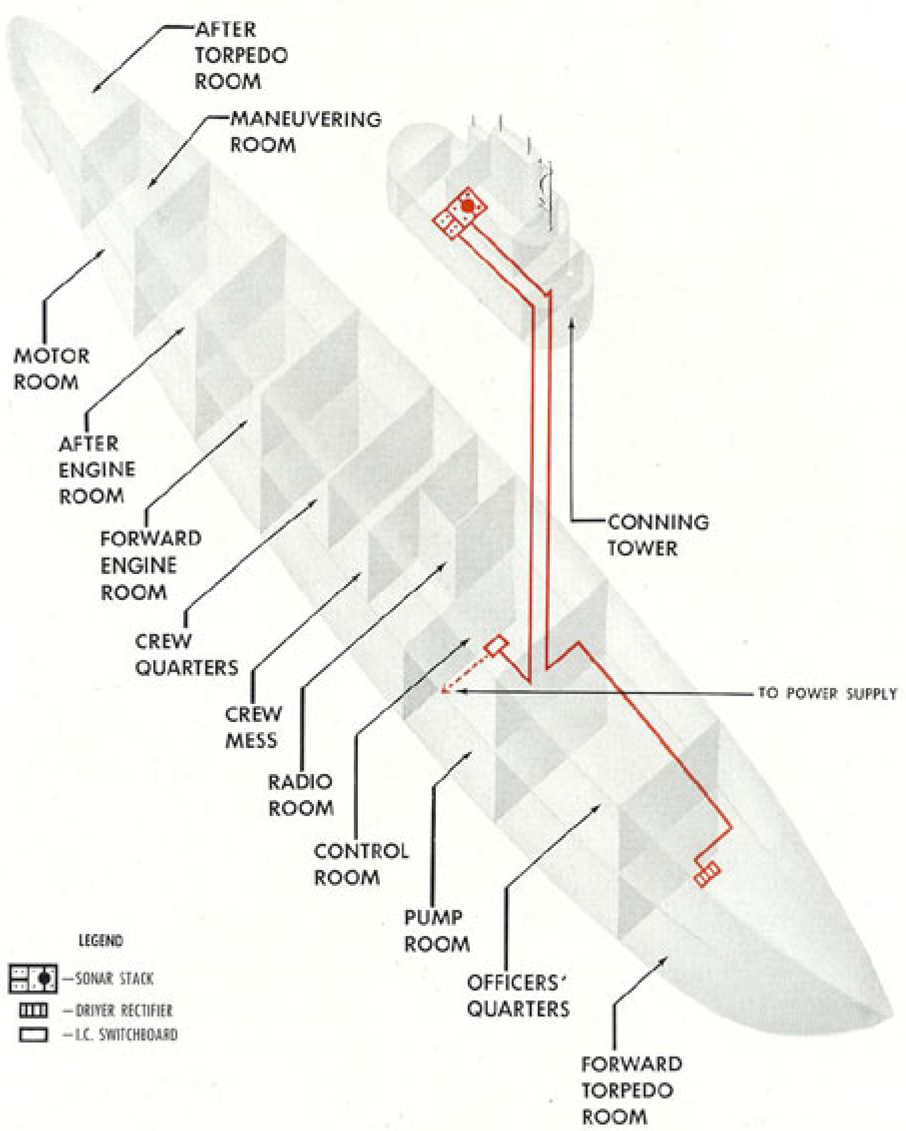


Figure 15-1. Schematic diagram of underwater sound system.

Figure 16-1 GENERAL LAYOUT DIAGRAM OF GENERAL ANNOUNCING AND SUBMARINE CONTROL ANNOUNCING SYSTEMS.

16
COMMUNICATION AND ALARM SYSTEMS

A. DESCRIPTION

16A1. General. The general announcing system provides a means of broadcasting orders and information by voice from any one of 3 stations, bridge, conning tower, and control room, simultaneously to all compartments of the submarine. The submarine control announcing system provides a means of 2-way loud-speaking voice communication between the bridge, conning tower, and control room, and between these stations, the 2 torpedo rooms and the maneuvering room. It is principally designed for the rapid interchange of orders, acknowledgments and information between the above stations in combat, and for this purpose may be regarded as part of the fire control system. The general announcing and the submarine control announcing systems are interconnected and utilize the same equipment.

Three alarm systems having distinctive tones and known as the general alarm, collision alarm, and diving alarm are incorporated in, and are a part of, the general announcing system. The general alarm, a single stroke repeated gong sound, calls all hands to their stations for battle and is used as an alarm for fire. The collision alarm, the sound of a motor siren, is the signal that collision is imminent or has occurred and is the order to rig the ship to minimize and localize the damage. The diving alarm is the sound of a motor-driven horn and is the signal to submerge the ship or to surface if submerged. Due to its importance, this system is paralleled by a set of motor-driven horns installed in certain key stations, which operate independently of the electronically produced signals in the general announcing system. They are provided so that the diving signal can be given even when the general announcing system has failed.

B. GENERAL ANNOUNCING SYSTEM

16B1. Description. Equipment

for the late fleet type general announcing system is manufactured by the Victor Division of the Radio Corporation of America. A detailed description of the equipment is given in the instruction book provided by the manufacturer.

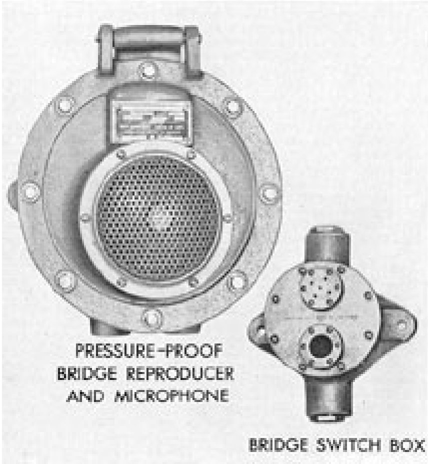


Figure 16-2. General announcing bridge units, switch box and bridge reproducer and microphone.

Power is supplied from the 120-volt alternating current bus on the I.C. switchboard through a double pole, single throw, fused switch. Circuit 1MC is provided for the general announcing system and circuit 7MC is provided for the submarine control announcing system. Circuit 7MC is closely tied in with circuit 1MC.

This same amplifier equipment is also used for the 7MC circuit. Normally, one channel is set up for use on the 1MC circuit and one channel for use on the 7MC circuit, but switches are provided so that in an emergency both circuits may be operated through either of the 2 individual amplifier channels.

16B2. Components. The system consists of the following components:

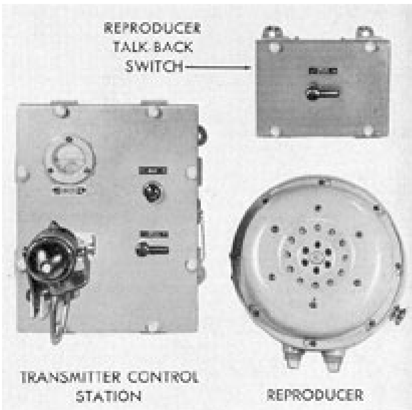


Figure 16-4. General announcing system showing reproducer talk-back switch, reproducer, and transmitter control station.

1. The transmitter control station, which contains a microphone, control switches, a volume indicator, and a socket into which a portable microphone may be plugged. There are 2 of these stations, one in the conning tower and another in the control room.

2. The signal generator, which produces the audio frequency signals that are broadcast over all reproducers for alarm signals. There are 2 signal generators located in a common housing in the 1MC stack in the control room.

3. The amplifier, which raises the energy level of the input voice or alarm signal high enough to operate the reproducers with adequate volume. There are two 120-watt amplifiers built into the 1MC stack; they are designated as channel A and channel B.

4. The reproducer, which converts the electrical output of the amplifier into sound waves; with proper connections, such as those available at the bridge reproducers, they can also be used as microphones. There are 19 reproducers installed for use on the 1MC circuit. The number installed in each location is shown in the table at the bottom of the page.

Supplementing the reproducers are 11 type H-9 horns which are operated by the diving

Figure 16-3. General announcing reproducer, class H.

alarm. Two of these horns are located in the forward engine room, 2 in the after engine room, and one horn in each of the following locations forward torpedo room, officers' quarters, control room, crew's mess, crew's quarters, maneuvering room, and after torpedo room.

An overhead fixture, non-watertight, with a green globe, is connected in parallel with the type H horns in each engine room for a visual signal.

The reproducers on the bridge can be used either on circuit 1MC or 7MC. When it is desired to talk over circuit 7MC, it is necessary only to speak into the reproducer. If it is desired to talk over circuit 1MC, the pressure-proof switch located near the reproducer must be held down.

The reproducers on the bridge can be cut out by a switch labeled BRG. 1MC-7MC at the control panel on the amplifier. The water pressure from submerging also cuts out these reproducers.

LOCATION	NO.	LOCATION	NO.
Forward Torpedo Room	2	Crew's Mess	1
Officers' Quarters	1	Crew's Quarters	1
Control Room	1	Forward Engine Room	3
Bridge	2	After Engine Room	3
Conning Tower	1	Maneuvering Room	1
Radio Room	1	After Torpedo Room	2

16B3. Operation. This system signal, and the collision alarm, or

provides one-way voice communication from the bridge, conning tower, and control room to all compartments and also provides the means for generating, amplifying, and reproducing the general alarm, or gong signal, the diving alarm, or horn siren signal, in all compartments. The general alarm takes precedence over voice communication. The diving alarm takes precedence over general alarm and voice, and the collision alarm takes precedence over all other uses of the IMC circuit.

C. SUBMARINE CONTROL ANNOUNCING SYSTEM

16C1. Description. This circuit, known as the 7MC circuit, is closely tied in with circuit 1MC. (See description of circuit 1MC in the preceding sections,)

16C2. Operation. Circuit 7MC provides two-way voice communication between the bridge, conning tower, control room, forward torpedo room, after torpedo room, and maneuvering room.

On this circuit, all reproducers can be used as microphones by pressing the TALK switch. In the normal position the bridge reproducers are connected for TALK and all other reproducers for LISTEN. Closure of the TALK switch at any other location connects that reproducer to the input of the amplifier for use as a microphone and transfers the bridge reproducers to LISTEN.

16C3. Older installations. Many of the earlier fleet type submarines were equipped with the 1MC system only, with microphone transmitter stations on the bridge and in the conning tower and control room and with provisions for use of throat microphones at the forward and after torpedo tube nests if desired. Intercommunication by voice between the bridge, conning tower, control room, torpedo rooms, and in some installations, the maneuvering room, was provided by means of a conventional interoffice type of loudspeaking system. The 1MC systems in these submarines did not incorporate the electronic signal generators for the alarm systems but were equipped with the auxiliary horns for the diving alarm system. The general alarm and collision notes were produced by picking up by microphones, and amplifying the sounds produced by an electric gong and an electric siren located in the control room, and transmitting these sounds over the 1MC system.

D. GENERAL ALARM SYSTEM

16D1. Description. Late fleet type submarines use 2 manual contact makers which are installed in the control room and system which takes precedence over voice inputs to the 1MC system but is subservient to inputs either from circuit CA or circuit GD.

in the conning tower. The latter is connected through a double pole, single throw, unfused cutout switch on the I.C. switchboard to the 1MC system. The general alarm circuit designation is G.

16D2. Operation. Operation of either contact maker energizes a circuit in the 1MC This circuit causes the signal generator in the 1MC system to generate a gong sound which will continue automatically at a rate of about 100 strokes per minute for a period of 10 seconds, and is sounded over all loudspeakers of the 1MC system.

E. COLLISION ALARM SYSTEM

16E1. Description. Three manual contact makers are installed, one in the control room, one in the conning tower, and a third on the bridge. The latter two are connected through separate double pole, single throw, unfused cutout switches on the I.C. switchboard to the 1MC system. The collision alarm circuit designation is CA.

16E2. Operation. Operation of any contact maker energizes a circuit in the 1MC system that takes precedence over all other circuits using the 1MC system and produces electronically a siren signal which is sounded over all the 1MC loudspeakers.

F. DIVING ALARM SYSTEM

16F1. Description. Three manual contact makers are installed: one in the control room, one in the conning tower, and the third on the bridge. The latter two are connected through except the CA circuit, to which it is subservient. This circuit causes the signal generator of the 1MC system to generate electronically the sound of a klaxon horn which is sounded over all

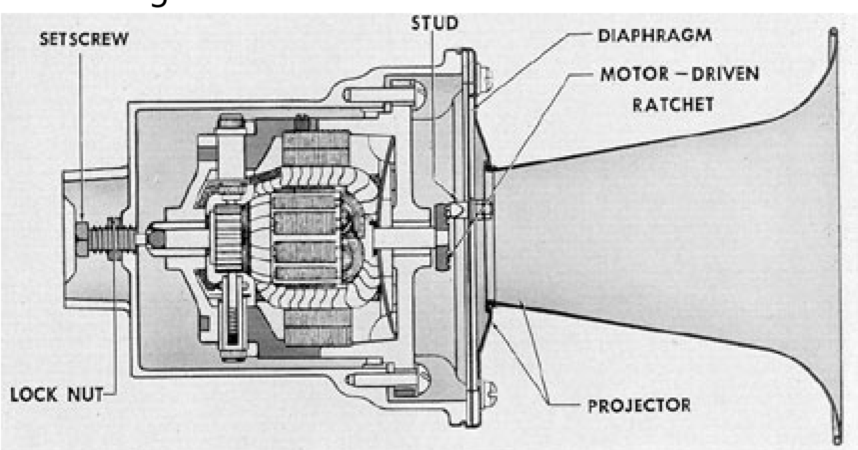


Figure 16-5. Motor-operated horn, type H-9.

separate double pole, single throw unfused cutout switches on the I.C. switchboard to the 1MC system. The diving alarm circuit designation is GD.

16F2. Operation. Operation of any contact maker energizes a circuit that takes precedence over all other circuits using the 1MC system loudspeakers of the 1MC system. Simultaneously, a relay operates to energize auxiliary H-9 horns located in each compartment having a 1MC loudspeaker except the bridge, conning tower, and radio room, which are not equipped with H-9 horns.

G. COMMUNICATION AND ALARM SYSTEM MAINTENANCE

16G1. General maintenance. All components of the system should be subjected to a routine inspection. This inspection should cover an examination of relay contact and switch action and in case of the amplifier, plate readings should be checked by means of the test buttons and jack with the circuit analyzer.

Relay contacts should be periodically cleaned. This is easily done by running a piece of bond paper between the contacts, holding the relay manually in such a position that the contacts are closed on the paper.

Inspection of a routine nature should also cover the removal of accumulated dust and dirt from the amplifier cabinet and other apparatus being inspected. A bellows blower is convenient for the removal of dust from the amplifier cabinet and the relay panels.

Units other than the amplifier should be checked for electrical connections and loose mechanical parts such as mounting bolts and similar items.

A thorough and frequent routine inspection will, in many cases, prevent subsequent system failure. Any parts that are in doubtful operating condition should be readjusted or replaced.

The manufacturer's instruction book should be consulted for complete details of maintenance, construction, and operation.

H. SOUND-POWERED TELEPHONE SYSTEM AND TELEPHONE CALL CIRCUITS

16H1. Description of sound-powered telephone. A sound-powered telephone is a telephone system in which the

Each station consists of a jack box into which a headset can be plugged. The box is equipped with

power comes from the sound of the voice rather than from batteries.

Vibrations from the voice cause vibration of a diaphragm in the transmitter. Attached to the inside of the diaphragm is a delicate needle called the armature. Surrounding this armature is a coil of fine wire, held in place by a magnet. Every time the diaphragm vibrates from the sound of the voice, the armature also moves inside the coil. This induces a current in the coil which passes through the line to a receiver. Internally, the receiver is constructed exactly like the transmitter. Thus, the current from the transmitter passes through the coil in the receiver causing its diaphragm to vibrate and reproduce the speaker's voice.

This type of telephone is supplied in both the conventional handset form and the headset type which consists of a headset and a separate transmitter mounted on a breastplate and supported by a neckstrap.

16H2. Circuits and stations, battle telephone system. The telephone system is divided into 2 circuits, the XJA (handset) used for routine ship's service communication, and the JA (headset) used on all battle control stations. The installations vary on different ships. The following is a description of a recent fleet type installation.

There are 2 independent JA circuits with 8 stations. One circuit runs from the spotter's a luminous disk marked with the identifying letters of the circuits.

Headsets are stowed in lockers near the jack boxes in the forward and after torpedo rooms and maneuvering room, on stowage hooks in the control room, and in the chart table in the conning tower.

The XJA system consists of 12 circuits running from the same switch box in the control room which also serve the JA system. The circuits connect to stations located as follows:

1. forward torpedo room
2. wardroom
3. captain's stateroom
4. forward battery space
5. control room
6. conning tower
7. radio room
8. crew's mess
9. forward engine room
10. after engine room
11. maneuvering room
12. after torpedo room

Each station consists of a jack box with a type L handset wired into it and held in a shockproof clip. A headset can also be plugged into any jack box if desired.

The switch box is located between the periscope walls in the control room, and facing to starboard has 20 toggle switches. Twelve of the switches in the 3 left-hand vertical rows serve the circuits of the XJA system, and 5 in the 2 right-hand vertical rows serve the JA system. The other 3 switches are spares.

position on the No. 2 periscope support to a headset receptacle at the 4-inch gun. This circuit has no interconnection with any other circuit. The other JA circuit has 5 lines running from the switch box in the control room to jack boxes located as follows: forward torpedo room (2 outlets in 1 circuit), control room, conning tower, maneuvering room, and after torpedo room. Each station may be independently cut out by means of toggle switches in the switch box in the control room.

16H3. Telephone switchboard. The telephone switchboard is made up of several small single throw, double pole switches. Each pair of telephone leads to each handset and each headset is connected to its own switch on the switch board.

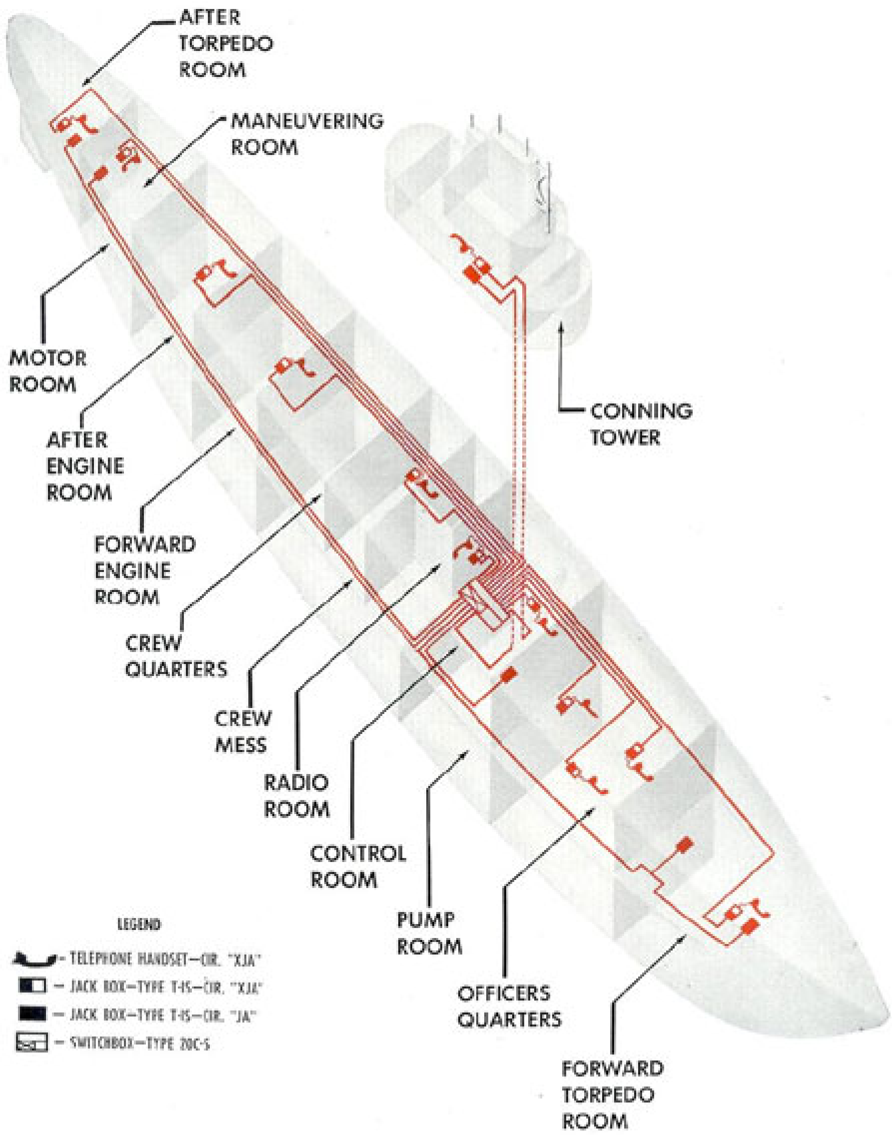


Figure 16-6. Schematic diagram of sound-powered telephone system.

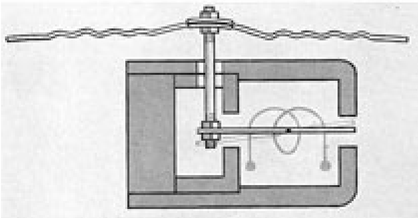


Figure 16-7. Sound-powered telephone diaphragm and armature.

One of the 2 sets of bus bars on the back of the switchboard makes up the JA bus, the other the XJA bus. Switches connect the respective JA and XJA phones to their respective buses. Thus, the JA and XJA circuits are common talking bus circuits and only one conversation can take place at a time over each bus.

Provisions are made to cross-connect the XJA and JA bus by means of either a crossconnect switch on some boards, or by means of a patching cord. The patching cord is a plain, 2-conductor, rubber-covered cable about 3 feet long with a jack plug on either end.

Each switch on this type of board has a jack connected to it. To cross-connect with the patching cord, plug one end of it into any JA switch and the other end into any XJA switch. Normally all switches are in the CLOSED position. The patching cord thus connects the JA and XJA bus together in the same way as the cross-connect switch previously mentioned. Any two phones can also be connected together by patching cords.

CAUTION. As previously described, the voice causes the transmission voltage to be generated in the units. Neither the telephone switch-board nor the telephone circuits are connected in any way to an outside source of electrical power. Never plug in or connect any part of the telephone switchboard or any headset or handset to any light or power connection as this will burn out the coils of the units.

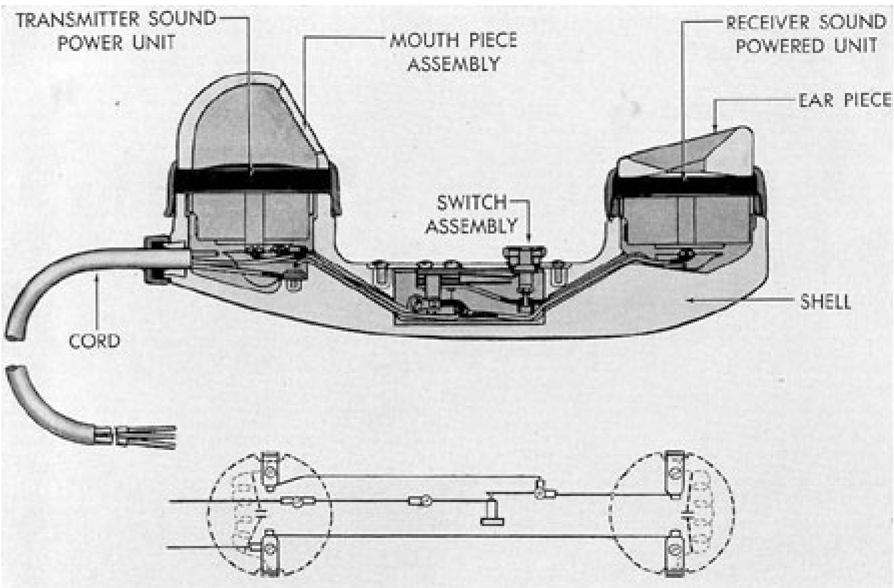


Figure 16-8. Sectional view and wiring diagram of sound-powered telephone handset.

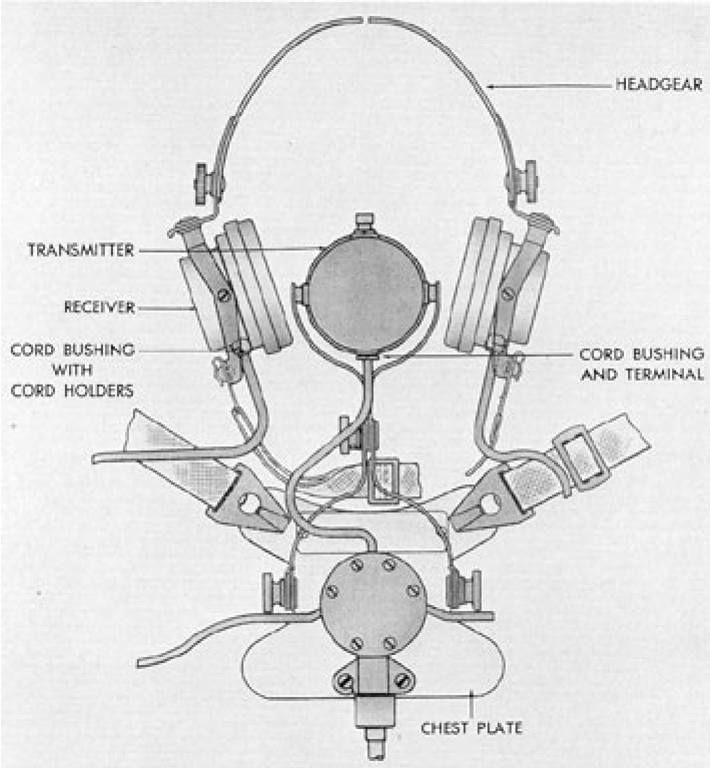


Figure 16-9. Headset sound-powered telephone.

16H4. Operation. it should be noted that the headset as well as the handset is made of delicate parts and must therefore be worn in the correct position, used carefully, and properly stowed. Telephones that are out of order may prevent other telephones on the circuit from working properly.

In the event of a casualty to the transmitter on the headset telephone, it is possible to speak into one earpiece while listening through the other. In the event of casualty to the earphones on a headset, hold the transmitter button down and receive and transmit with the transmitter.

With the headset telephone, push the button only when speaking; it is not necessary to push the button while listening. With the headset telephone, the button is held down when speaking and listening. It is a bad practice to keep the button taped down or held down by a rubber band as this will permit outside noise to get into the circuit. All the power required for operation is generated by the voice; no other source of power is needed; hence, it is necessary to speak loudly and clearly in order to supply the necessary power.

16H5. Maintenance. The equipment must always be handled carefully. Time after time, this equipment has been the only means of communication remaining between various parts of the submarine when other sources had

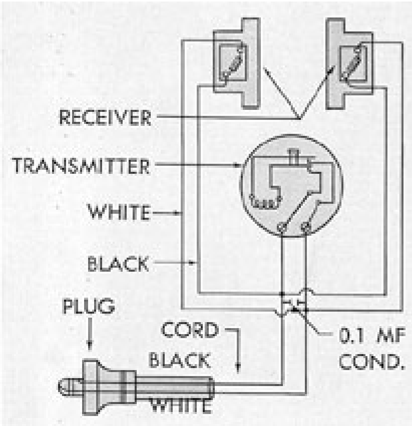


Figure 16-10. Headset wiring diagram.

become inoperative due to power failure during combat. Constant exposure to moisture will

Figure 16-12. Ship's service handset telephone.

harm the instruments. Keep them as dry as possible at all times.

Rubber cables should be inspected frequently and renewed when they show excessive wear. Some of the wires in the system are very fine and should therefore be handled carefully to avoid breaking them.

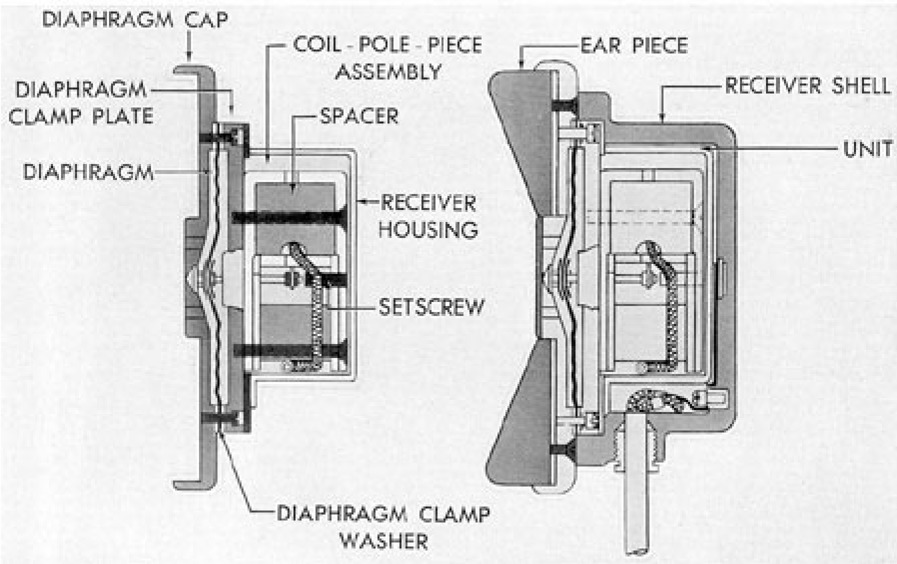


Figure 16-11. Sectional view of receiver unit.

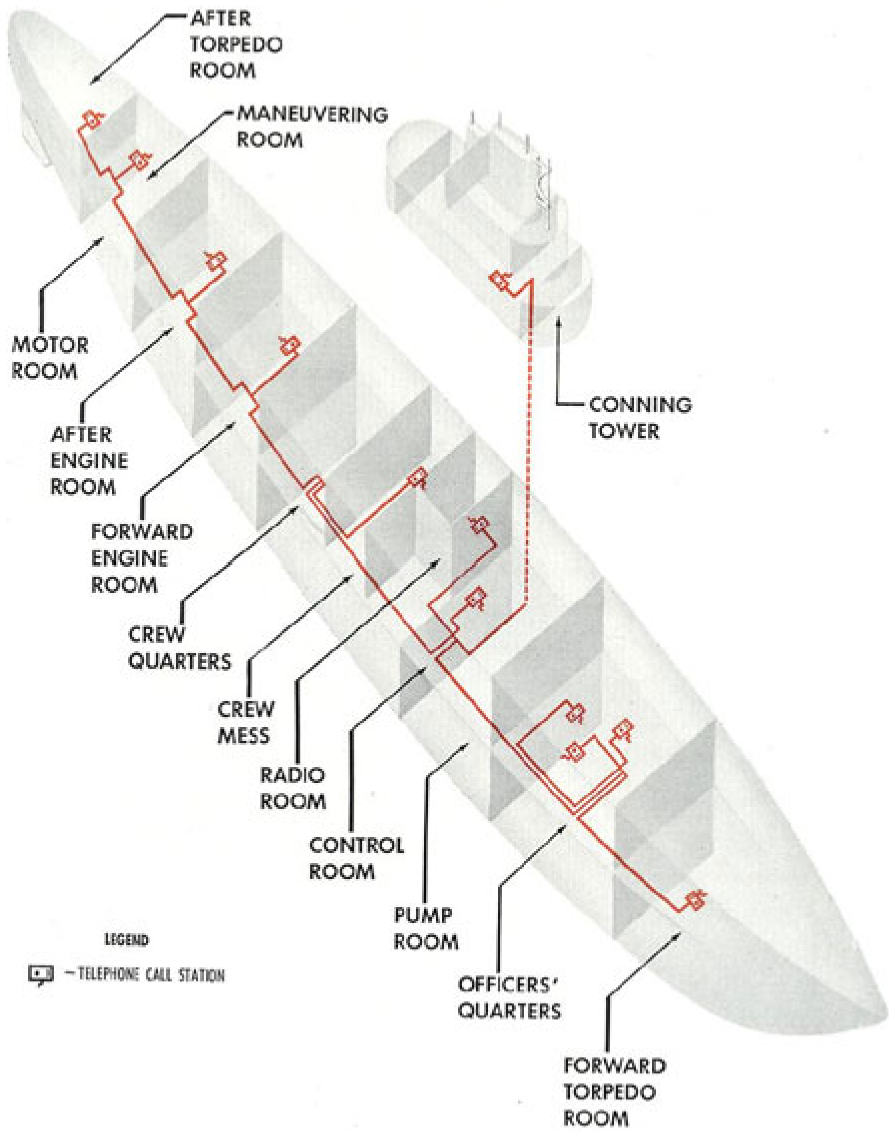


Figure 16-13. Schematic diagram of telephone call circuit.

I. TELEPHONE CALL CIRCUIT

16I1. Description. All call stations are connected with TTHFA-15 cable (24 active conductors and 6 spares). The cable to the conning tower goes through a, cutout switch located on the hull over the action cutout switchboard. The call circuit letter marking is E. The system consists of a rotary switch and a 115-volt bell mounted at each handset station, and the connecting cable. The rotary switch has a dial, operated by the switch shaft, and marked to voltage. It is a separate and complete circuit and is in no way connected to the telephone switchboard or to any part of the telephone circuit.

show the various compartments and stations with which the system connects.

Any station can be called from any other station by setting the selector switch to the station desired and then pressing the call lever. This completes the circuit and operates the 115-volt bell at the designated station or compartment. The circuit is operated on either 115-volt a.c. or d.c., depending upon the type of bell, supplied from a switch on the I.C. switchboard. Some later submarines are equipped with handcranked signal generators and "howlers" at each call station. Such a system requires no supply

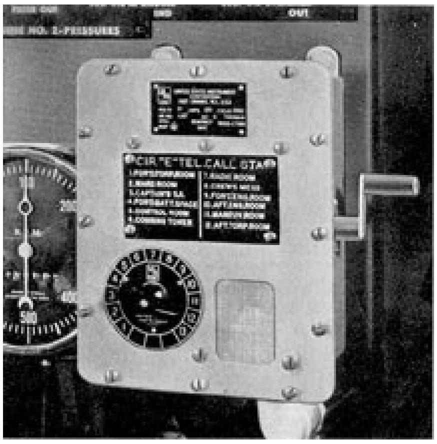
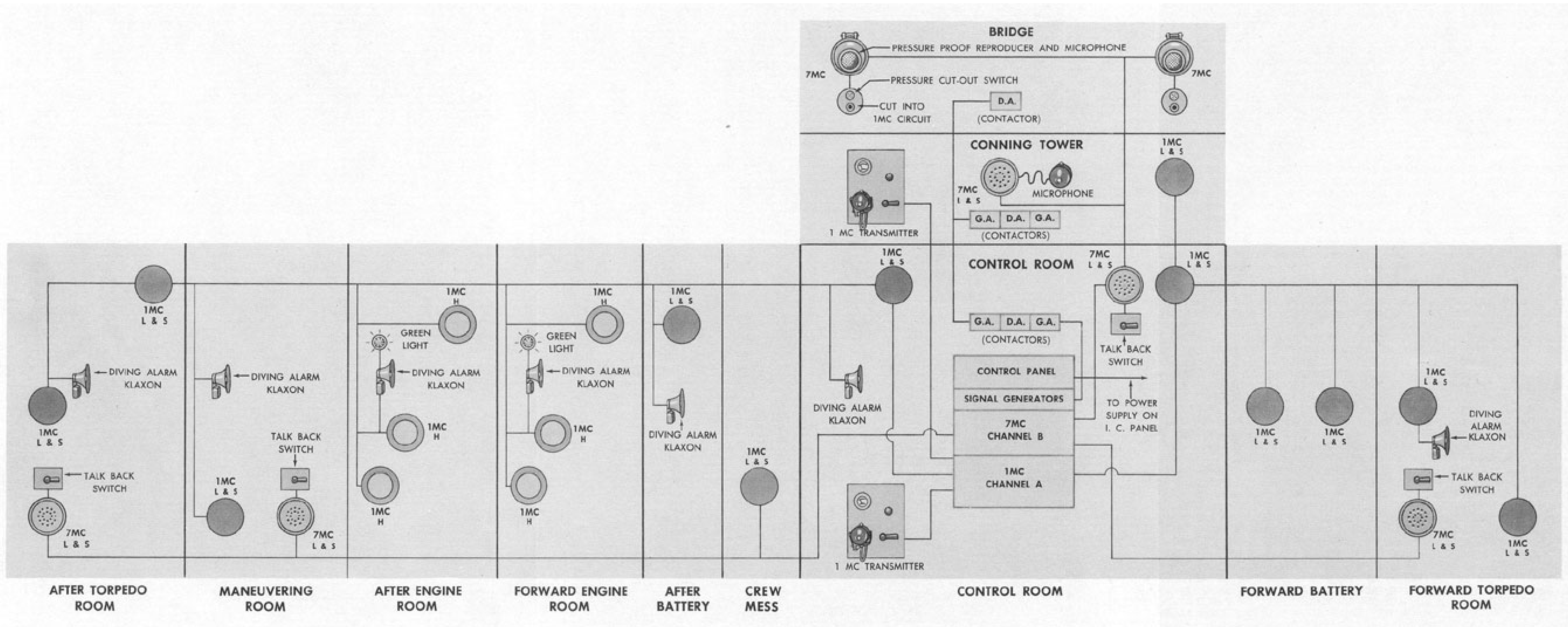


Figure 16-14. Telephone call bell station.

Previous Chapter   Sub Elec. Home Page   Next chapter

Figure 16-1 GENERAL LAYOUT DIAGRAM OF GENERAL ANNOUNCING AND SUBMARINE CONTROL ANNOUNCING SYSTEMS.

Sub Elec. Home Page



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17
GYROCOMPASS, AUXILIARY GYROCOMPASS, AND DEAD RECKONING ANALYZING INDICATOR AND TRACER SYSTEMS

A. THEORY OF THE GYROCOMPASS

17A1. Construction of a gyroscope. A free gyroscope is a wheel, constructed similarly to a flywheel and suspended with 3 degrees of freedom. (See Figure 17-1.) The gyroscope may spin around the spinning axis, and turn around the horizontal axis and the vertical axis. The center of mass of the wheel is at the intersection of the 3 axes. The gyro wheel should be constructed so as to have as much material near the rim as practicable and to run at high speeds. Naturally it must also be well-balanced and be as frictionless as possible.

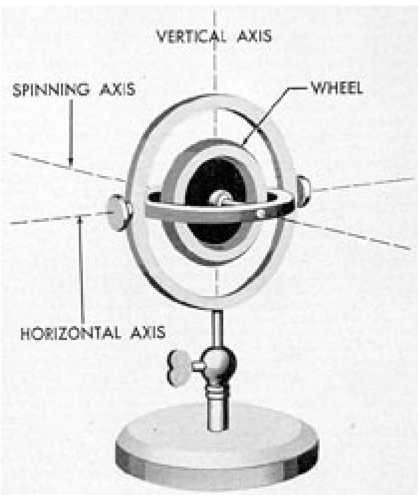

Figure 17-1. A free gyro.

17A2. Properties of a gyroscope. Gyroscopic phenomena are exhibited in all rotating bodies. Common examples are a spinning top, a car going around a curve, and a moving bicycle.

All known gyroscopic phenomena are dependent upon two properties of the gyroscope: 1) rigidity in space and 2) precession.

Rigidity in space is manifest in the gyroscope's tendency to remain pointing in the same direction at all times or to maintain its plane of spin parallel to itself. This is based on Newton's First Law of Motion which states: Every body continues in its state of rest or of uniform motion in a straight line, unless it is compelled by external forces to change that state.

17A3. Apparent rotation. If a gyroscope having complete freedom is spun continuously and is set at the earth's equator with its spinning axis horizontal in the east and west direction (see Figure 17-2), the wheel while spinning also apparently rotates about a horizontal axis that forms a right angle with the spinning axis. This apparent rotation proceeds at the rate of a single revolution in a day. Actually, however, the gyro

spinning axis remains parallel to its original position in space, though the gyro is carried along with the earth by the revolution of the latter about its polar axis. Thus, as shown in Figure 17-2, at the end of 3 hours the west end of the axle, viewed looking north, is depressed 45 degrees, and at the end of 6 hours it is vertical to the surface of the earth, having been carried through 1/4 of a revolution in 1/4 of a day. At the end of 12 hours, the axle is again horizontal, but its ends are reversed as viewed by an observer looking north. Actually the gyro axle still is parallel to its original position in

space and is pointing in its original direction in space. The apparent motion continues, and at the end of a complete revolution of the earth in 24 hours, the original position of the gyro axle is regained.

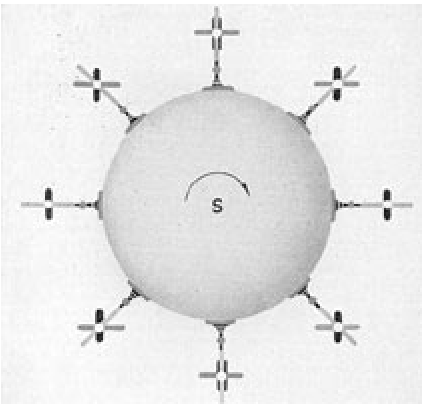

Figure 17-2. Gyro spinning at equator with its axis horizontal.

If a gyro with complete freedom is spun with the gyro axle horizontal at either the North or South Pole of the earth the axle will be at a right angle to the polar axis of the earth. But since a spinning gyro maintains the movement of the gyro axle corresponds with a daily period (Figure 17-5) and is partly about the vertical line passing through the center of the earth, and partly about the horizontal axis of the gyro.

17A4. Resting position. If the gyro is set spinning at the equator, with the gyro axle in the meridian and horizontal, the gyro axle will remain horizontal and in the meridian. Thus, the axle would continue to point north. This is equivalent to pointing north and parallel to the earth's polar axis, as illustrated in Figure 17-6, and there would be no apparent rotation. The gyro axle remains parallel to the earth's axis, though carried around it by the earth's rotation. Furthermore, the gyro axle remains stationary relative to the surroundings on the earth, although still rigid in direction relative to space. A condition in which those conditions prevail is

direction of its plane of rotation in space and the direction of its axis in space, it has an apparent motion about its vertical axis (Figure 17-3).

It should be noted that at the poles the apparent rotation is entirely about a vertical axis, but at the equator the apparent rotation is entirely about a horizontal axis.

If a gyro with complete freedom is spun at an intermediate latitude, with the gyro axle horizontal and in the meridian, the gyro axle will neither be parallel to nor at a right angle to the earth's axis, but will be at an angle to it equal to the latitude, as shown in Figure 17-4.

Rigidity of direction in space, or gyroscopic inertia, will therefore cause the gyro axle to rotate apparently about a line (A-B, Figure 17-4) passing through the center of the gyro parallel to the polar axis of the earth. This apparent termed a resting position, and it is the only resting position at the equator. The numbers in Figure 17-6 indicate the hours.

At high latitudes, the only true resting position for a gyro with complete freedom is that in which the gyro is set spinning with its axis parallel to the earth's polar axis. For latitude 50 North, the gyro, spinning in its true resting position, would be tilted so that the gyro axle would make an angle with the horizontal equal to the angle of latitude as shown in Figure 17-7, with the gyro axle in the meridian and the north end of the gyro axle pointing upward.

However, there are reasons for this tilt being impracticable with respect to gyrocompasses. A gyrocompass must have the gyro axle nearly horizontal. Means must therefore be applied to secure a resting position in the meridian and in the horizontal. Accordingly the axle of the gyrocompass is parallel to the polar axis of the earth only when the compass is operating at the equator.

17A5. Effect of applied force of translation. A completely free gyroscope may be moved anywhere or carried around by the earth's rotation without altering the direction of its axle relative to space. It is therefore unaffected by forces of translation.

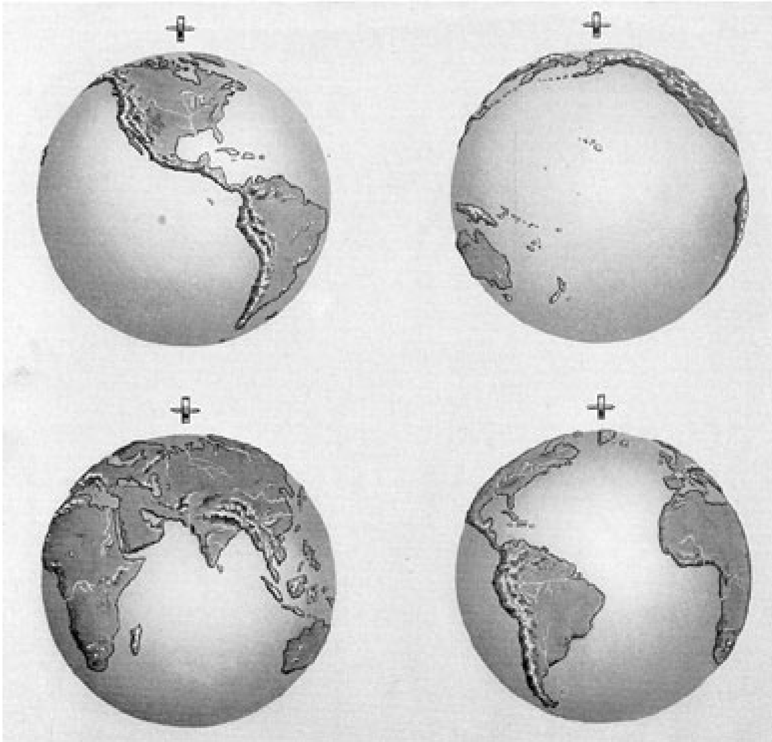

Figure 17-3. Gyro spinning of pole with its axis horizontal.

17A6. Precession. The gyroscopic property referred to as precession may be demonstrated by applying a force to the gyroscope so as to tend to change the plane of rotation of the spinning wheel.

If the gyroscopic wheel is spinning in the upward direction as indicated by the arrow B and a force is applied to turn the gyroscope about the horizontal axis (Figure 17-8), it will be found that there is a great resistance to the force, and instead of motion taking place in the direction of the applied force the wheel turns around in the direction of the arrow labelled PRECESSION. It continues to turn in that direction during the application of the force until the plane of spin of the wheel coincides with the plane of the force or until the force is removed. When the direction of spin is reversed and the experiment is repeated (Figure 17-9), similar phenomena are exhibited, except that the wheel turns around in the opposite direction. The observed motion, precession, is always about an axis at a right angle to the axis of the impressed force.

17A7. Rule for precession. By comparing the final positions taken under conditions represented in Figures 17-8 and 17-9, respectively, it may be seen that in these experiments the wheel not only sets its place of rotation into coincidence with that of the force, but that the

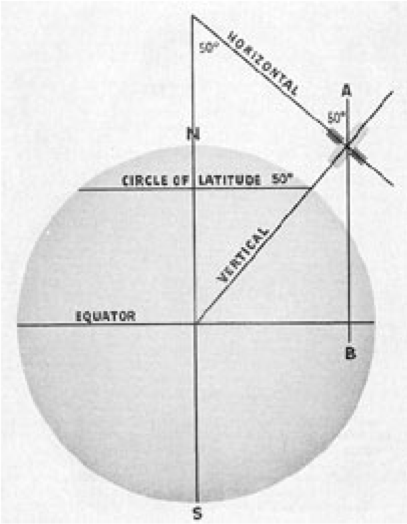

Figure 17-4. Gyro spinning at intermediate positions.

direction of rotation is also in coincidence.

The experiments may be repeated in many ways and the results will always be as expressed

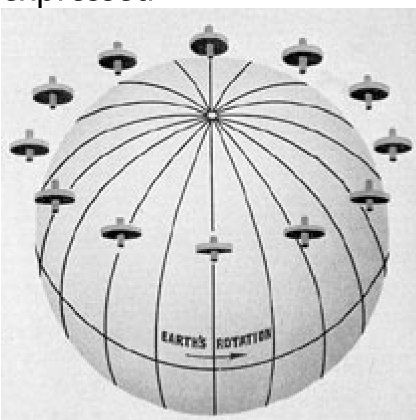

Figure 17-5. Gyro wheel with its rotating axis set in north-south position and level away from the equator moves about its horizontal and vertical axes.

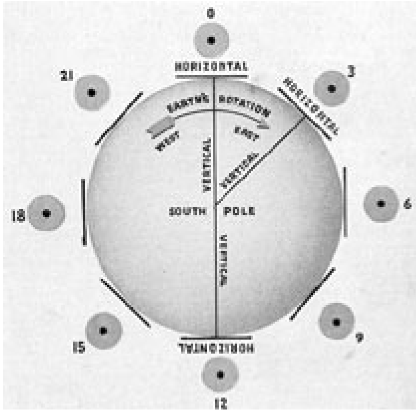

Figure 17-6. Resting position of a gyro spinning at equator.

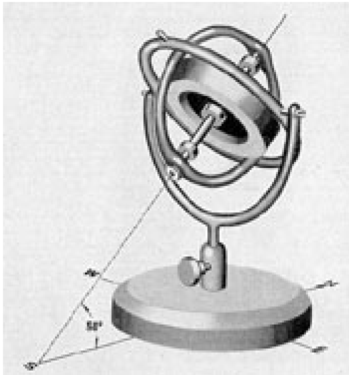
Figure 17-7. Resting position of a gyro spinning at high latitudes.

by the following rule: The movement is such as to place the plane and direction of spinning rotation of the wheel in coincidence with the plane and direction of the force by the shortest path.

17A8. Continuous precession. When the applied force acting on the gyro system is arranged

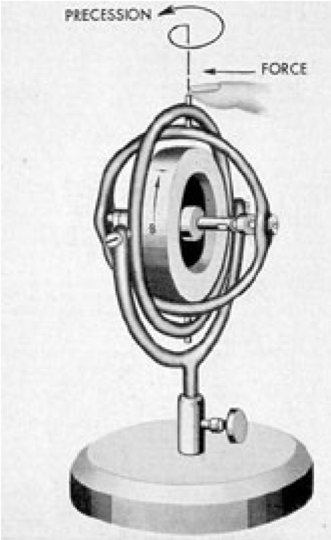

Figure 17-8. Effects of applied force on vertical axis with gyro wheel spinning in upward direction.

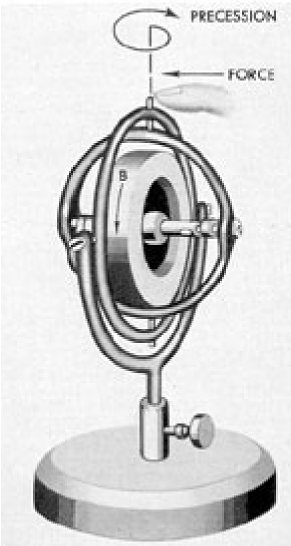

Figure 17-9. Effects of applied force on vertical axis with gyro wheel spinning in downward direction.

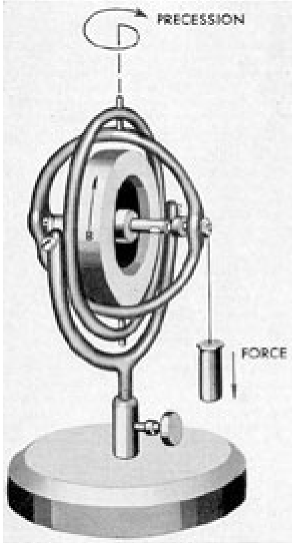

Figure 17-10. Continuous precession.

so that the force is constant, precession becomes continuous. This is illustrated in Figure 17-10, which shows a spinning gyro with horizontal axis and with :a weight hung on one end of the axle. The spinning wheel will turn about its vertical axis as indicated in Figure 17-10. The wheel continues to follow the weight and continuous precession results. Precession ceases immediately upon removal of the weight.

17A9. Relation of applied force to precession. The speed of precession is directly proportional to the applied force, and inversely proportional to the weight of the spinning wheel and to its speed in rpm.

B. FUNDAMENTAL CHARACTERISTICS OF THE GYROCOMPASS

17B1. Characteristics of the gyrocompass. It has been shown that if a spinning gyro wheel is placed on land at the equator, with the gyro axle parallel to the earth's polar axis, it will remain in horizontal and the torque is zero. The precessional motion is also zero because there is no torque. But the earth continues to rotate under the gyroscope, so the gyro axis now has a slight tilt

the meridian, because there is no force tending to deflect it. However, when it is placed on a ship it is subjected to the disturbing forces of a ship's motion, which deflect it from the meridian.

To be of use as a compass on board ship, the gyro wheel must remain rigidly in the meridian at any latitude and must be unaffected by the ship's motion.

Hence, a gyrocompass must be made to seek and hold the meridian against the friction of its supports and other disturbing forces. For example, a ship changing course turns about the compass, and as friction cannot be entirely eliminated, the friction of its support tends to deflect the gyro.

17B2. North seeking. The Arma compass is a pendulous gyro. It is made north-seeking by placing a weight below the spinning axis as shown in Figure 17-11.

Let us assume that the gyroscope is at the equator with its spinning axis horizontal and pointing to the east of the meridian. The north end of the gyroscope will appear to tilt upward since the gyro maintains its direction in space as the earth revolves under it. Gravity will attract the weight toward the center of the earth -straight down as shown in Figure 17-12. This pull of gravity has the same effect as an applied force or torque around the horizontal axis. Due to the direction of rotation of the wheel, clockwise looking at the south face, the precessional motion will take downward, and the torque or pull is reversed with the corresponding reversal of direction of precession. This downward tilting continues until the axis is pointing along the meridian where the precessional motion is the most rapid toward the east. At this point, the tilt diminishes, the torque diminishes, and finally the gyro axis is again pointing horizontally at the point where the oscillation first started.

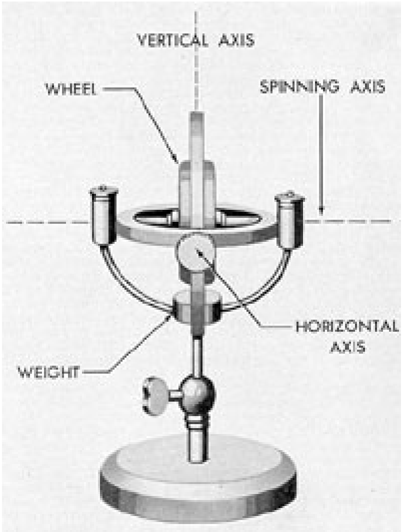

Figure 17-11. Simple pendulous type gyro.

The north end of the pendulous gyroscope oscillates back and forth across the meridian in a period of approximately 84.3 minutes. On each passage of the meridian of the north end of the spinning axis, the gyro is tilted either upward or downward. Also the axis points to the meridian only momentarily, making it useless as a navigational instrument. (See Figure 17-14.)

In order to make a compass of a pendulous

place to the west as shown in Figure 17-12.

As the upward tilting increases, the torque, or gravity pull, increases with a corresponding increase in the rate of precession toward the west. When the gyro is on the meridian, the maximum upward tilt of the axis is attained and the rate of precession is greatest. The tilt will now be reduced and with it the rate of precession, until the north end of the axis is

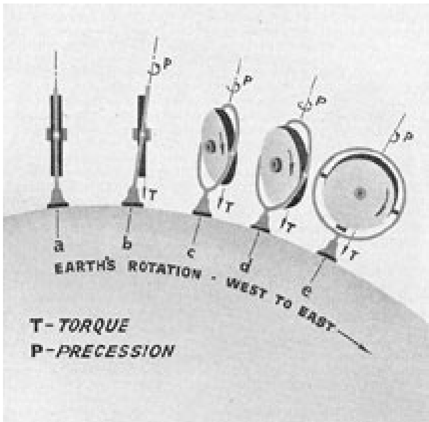

Figure 17-12. Effect of gravity and resultant precessional motion.

gyroscope it is necessary to cause it to point along the meridian at all times. To do this the oscillations must be damped out.

17B3. Damping the oscillations. In order to damp the oscillations, the Arma compass employs an arrangement called an oil ballistic. It consists of two tanks located on the north and south sides of the gyro wheel and connected at the bottom by a pipe.

Let us assume that the north end of the gyro axis points to the

weight is, therefore, reduced as the gyro axle approaches the meridian and the rate of precession is materially reduced. By properly proportioning the gyro's pendulous factor and the rate of transfer of oil, the initial oscillation may be completely suppressed or damped in about 2 1/2 cycles. (See Figure 17-15.)

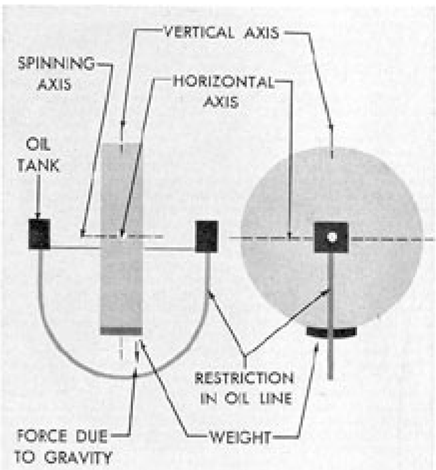

Figure 17-13. Oil ballistic arrangement for damping oscillation.

17B4. Continuous precession toward the meridian. In order that the gyro may be constantly in the meridian at all latitudes, it must be made to precess

east of the meridian, with the two tanks secured as shown in Figure 17-13, the axis horizontal, and with equal amounts of oil in both tanks.

The gyro axis then tilts upward, due to the earth's rotation, and at the same time oil flows to the south or low tank. The pendulous mass of the weight causes the gyro to precess toward the meridian, to the west. During this period oil continues to flow from the north tank to the south tank. The rate of flow is low, due to the resistance offered by the small passage in the pipeline. By the time the north axle of the gyro has reached the meridian, a considerable quantity of oil has been transferred from the north tank to the south tank. The excess oil gathering in the south tank provides a force which opposes the force of the weight. The effect of the continuously about its vertical axis to the west as fast as the earth is carrying the gyro off to the east.

In northern latitudes the gyro, if it maintains its direction in space, is no longer in the meridian, and hence after several hours it would indicate an error of large magnitude as shown in Figure 17-16 (dotted lines).

This constant westerly precession about the vertical axis is caused by a turning force about the horizontal axis. A force about the horizontal axis takes place only when the gyro is tilted upward or downward. In northern latitudes, the Arma gyro settles in the meridian with a slight upward tilt of the rotor axis, causing a turning force to the west due to the pendulous factor which keeps the compass in the meridian as shown in Figure 17-17.

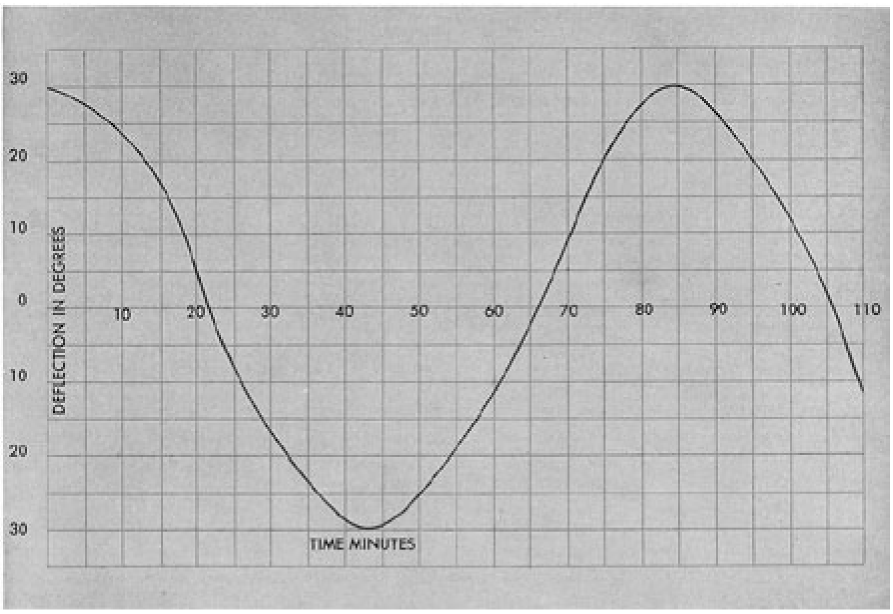

Figure 17-14. Effect of undamped oscillation.

C. CONSTANT MOTION ERRORS

17C1. General. This section deals with the errors encountered in the gyrocompass and the method of correcting them in the pendulous type compass when installed on board ship.

17C2. Speed error. The magnitude of the speed error is dependent upon the speed, course, and latitude of the ship in which the compass is installed. A ship at the equator is being carried around by the earth's rotation at a velocity of 900 knots. At any latitude other than the equator, this velocity becomes 900 times the cosine of the latitude. If a ship is steaming due west, its speed opposes that of the earth; if steaming due east its speed is added to the movement of the earth. Neither course causes a speed error, but both have a slight effect on the directive force of the wheel.

If, however, a ship starts at the equator and sails due north, its speed is at a right angle to the speed with which the rotation of the earth is carrying the gyrocompass around in space. Assume that the vessel in Figure 17-18 starts at A and is making a speed of 2,026 feet per minute or 20 knots, along the course line A-A'; the speed of rotation of the earth is 92,400 feet per minute along A-B. The actual speed and direction in which the compass is being carried around in space is A-C, and the actual axis about which it is carried around is not the earth's polar axis N-S, but an axis at a right angle to A-C. The gyro axle will, therefore, settle on a line N'-S' and not on the true meridian. The true north will be toward the east of the indicated north by an angle N'-A-N which will be 1.25 degrees for a speed of 20 knots. If the ship starts from the equator and sails due south, the deviation will be toward the opposite side, that is, the true north will be west of the indicated north. If the course is neither due north nor due south, the deviation will have a value between zero and 1.25 degrees. If the ship is at 60 degrees north latitude, steaming at 2,026 feet per minute, or 20 knots, due north as at E-E', and the earth's rotation at this latitude

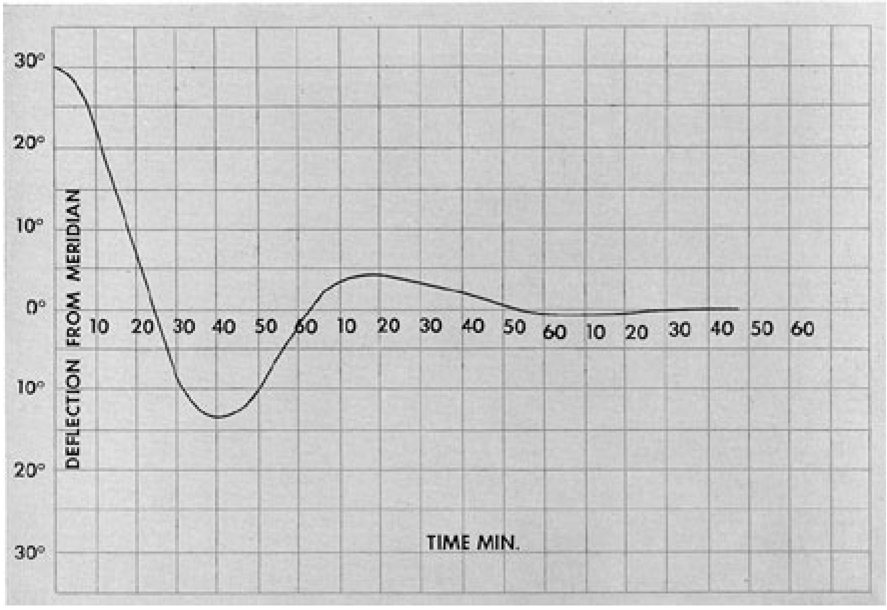

Figure-17-15. Effect of damped oscillation.

E-F is 46,200 feet per minute, the compass is being carried around with a velocity E-G and is being rotated about an axis N"-S" at a right angle to the resultant E-G. The axle will align itself with N"-S". Thus, in this latitude and at the given speed, the true north will be 2.5 degrees eastward of that indicated by the compass. On northeasterly-or northwesterly courses, the deviation will be between zero and 2.5 degrees.

17C3. Ballistic deflection error. In Figure 17-19, the gyro axis is assumed to be pointing along OA. ON is the true north. The angle NOA is the speed error for an assumed course of north and an assumed speed of 20 knots. For a true east course for any speed or latitude, the speed error is zero. Therefore, the axis of the gyro points along ON if the course is east. Let us suppose that the ship, which is on a northerly course and is traveling at a speed of 20 knots, should change to an easterly course. This change of course is made in about 2 minutes. During this precess to the east so that by the time the ship is headed east, the axis of the gyro will point along the line ON. If the gyro, by the time the ship is on an easterly course, is not pointing along the meridian ON, it will produce an erroneous reading on the compass and its repeaters.

Fortunately, the north end of the gyro will have a tendency always to precess toward its proper settling point on a change of course.

If the compass is to have the proper ballistic deflection during the time that the vessel is actually changing course, it must have a definite amount of pendulousness for the latitude which will make it precess exactly to the settling point required for the new course in a deadbeat manner. The ballistic deflection error is prevented in the Arma compass by varying the speed of the gyro rotors in accordance with the cosine of the latitude of the vessel's position. This variation in speed is effected by changing the speed of the motor generator through a field rheostat on the control panel.

time, the north end of the gyro must

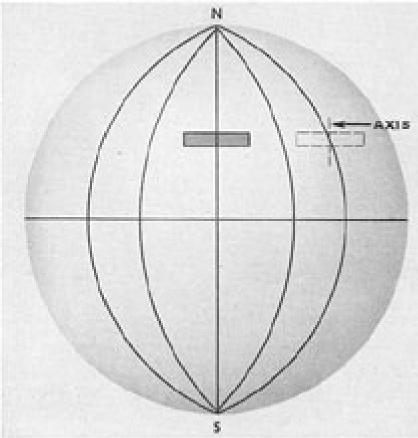

Figure 17-16. Gyro axis parallel to the north-south axis.

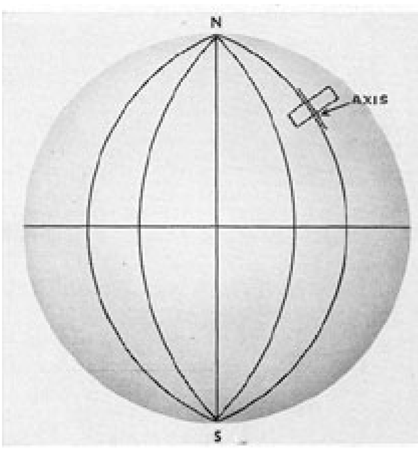

Figure 17-17. Gyro axis parallel to the meridian.

17C4. Ballistic damping error. The oil damping arrangement of the Arma compass allows a small quantity of oil to flow from one tank to the other when the compass is subjected to the inertia forces caused by acceleration or deceleration of the ship during a change of course or speed so that an unbalanced condition is set up. This unbalanced condition results in a precession about the vertical axis and causes an oscillation which must be damped out in the

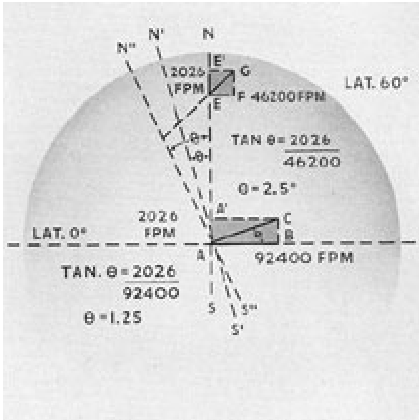

Figure 17-18. Speed course latitude errors.

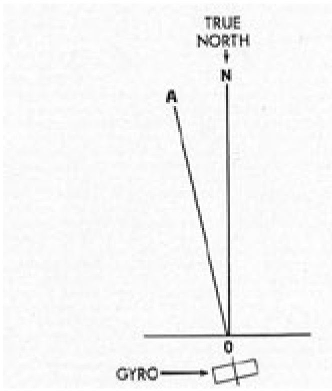

Figure 17-19. Ballistic deflection error, ship on northerly course.

regular manner. In all the later Arma compasses, damping is eliminated for changes of course of 15 degrees or over, thereby eliminating this error. This is accomplished by a solenoid-operated valve controlled by contacts in the follow-up system.

17C5. Quadrantal errors. Centrifugal forces resulting from roll and pitch are neutralized in the Arma compass by maintaining uniform distribution of the sensitive element masses in the horizontal plane. This is accomplished by supporting the sensitive element on a hollow steel

sphere which floats in a concentric tank of mercury.

Acceleration forces caused by roll and pitch are neutralized in the Arma compass by east-west stabilization of the sensitive element. This is accomplished by using two gyroscopes instead of one. In this way, swinging of the compass in the east and west direction is prevented, giving both east and west stabilization as well as north and south.

17C6. Latitude error. The Arma compass settles on the meridian in a tilted position and has no latitude error, hence correction for this error is not required.

17C7. Speed error. The Arma compass has a correcting mechanism that compensates for speed error so that the true course readings are indicated on the compass card and repeaters.

D. UNITS OF THE COMPASS EQUIPMENT

17D1. Units comprising the compass equipment. The principal units of the compass equipment are as follows:

1. Master compass (Figure 17-20). This includes the north-seeking element, its housing, and a follow-up mechanism.

2. Control panel (Figure 17-21). This panel carries meters, switches, and ballistic adjustment for the master compass.

3. Repeater panel. This panel is mounted directly below the control panel, on the same frame. It carries switches for controlling the repeater compasses.

4. Follow-up panel. This panel carries the vacuum tubes that drive the follow-up mechanism of the master compass. It is mounted directly below the repeater panel and on the same frame.

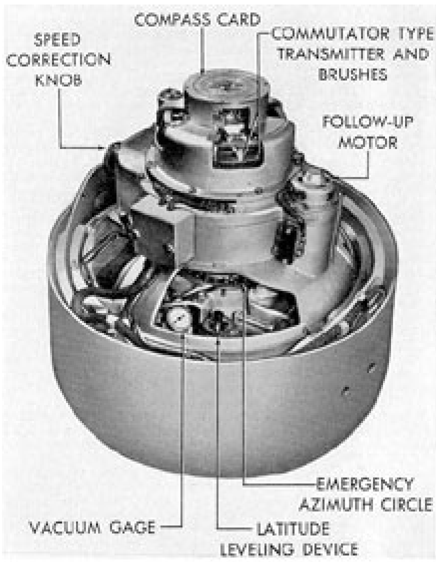

Figure 17-20. Arma master compass installed, binnacle cover removed.

5. Motor generator set. This unit converts the ship's supply to a three-phase, variable frequency supply for driving the gyros.

6. Repeater compasses. These receive and indicate the ship's heading at remote stations.

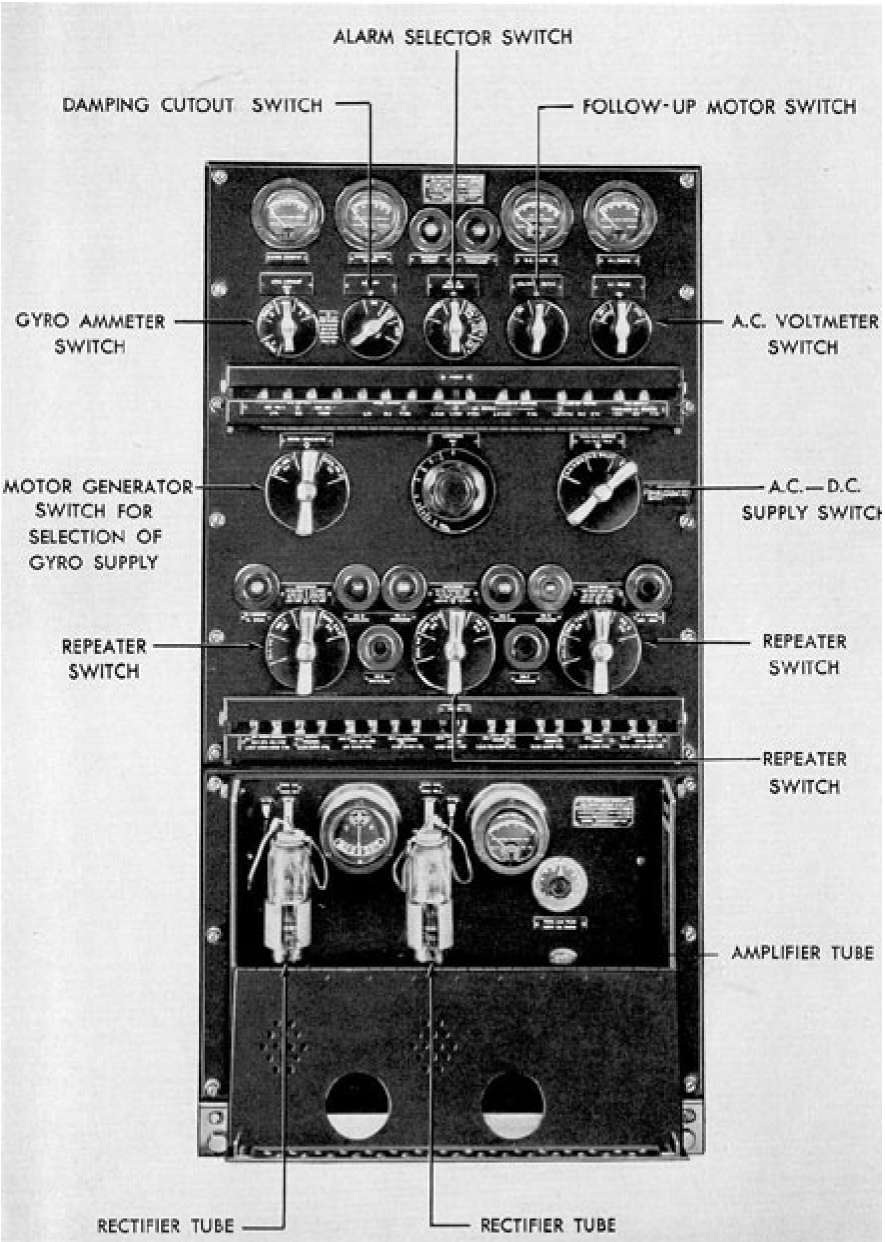

Figure 17-21. Arma master compass control, repeater and follow-up panels.

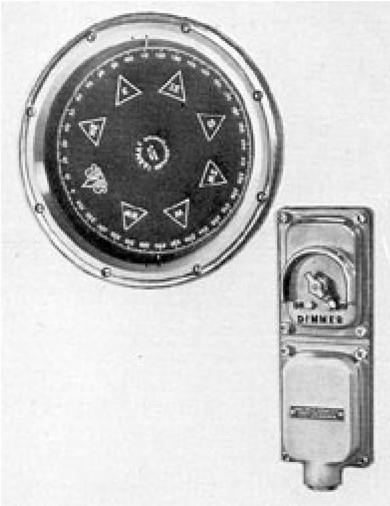

Figure 17-22. Single dial repeater with dimmer.

Figure 17-23. Conning tower double dial steering unit with dimmer switch.

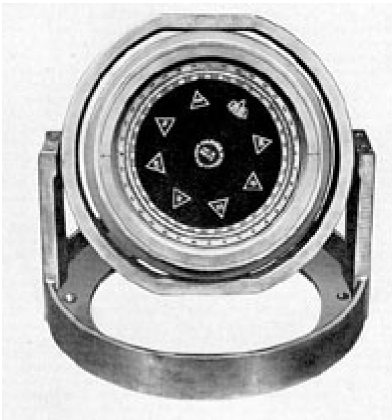

Figure 17-24. Gimbal-mounted double-dial bridge pelorus, pressure-proof type.

E. THE MASTER COMPASS

17E1. Components of the master compass. The master compass shown in Figure 17-25 is the principal unit in the compass equipment. For purposes of description, the master compass may be divided into its major parts as follows:

17E2. Binnacle stand. The binnacle stand (Figures 17-25 and 17-26) which supports and encloses the whole master compass, is made in 3 sections. The center section is cylindrical and connects the upper and lower sections. The bottom of card may be read. Near the forward and after sides of the cover are 2 hinged doors for gaining access to the speed correction knob and other parts. These doors are provided with hasps and padlocks.

17E3. Gimbal rings. To provide a relatively stable support for the compass, the frame, consisting of bowl and spider, is supported on gimbal rings (see Figure 17-25) within the binnacle stand. The outer ring is trunnioned fore and aft in the binnacle midsection on ball bearings mounted in bakelite

the lower section is bolted to the binnacle base.

The midsection carries the gimbal rings. It is rigidly bolted to the lower section. Inside the lower section near its base, 4 terminal blocks are fastened, for making connections with the control panel.

The binnacle top section is a cover attached to the midsection by latches. Its upper surface is shatterproof glass through which the compass

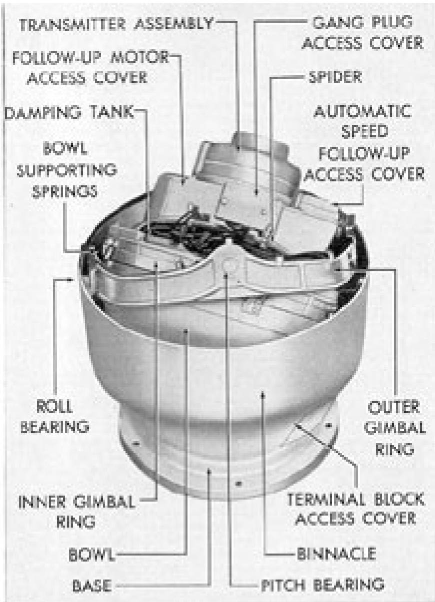

Figure 17-25. Master compass with cover removed showing position for 15 degree pitch and 35 degree roll.

bushings to insulate the rings from the binnacle. The inner ring is trunnioned athwartship within the outer ring. To prevent the compass frame from swinging excessively in the rings when the ship rolls, the inner ring carries on its upper surface 3 steel damping tanks partially filled with mercury.

17E4. Spider and bowl. The compass frame consists of a large bowl suspended from the inner gimbal ring by 16 helical springs, and a spider attached to the upper surface of the bowl. (See Figure 17-25.) The supporting springs are divided into 8 sets of 2 springs each. This construction allows freedom of the suspended parts in the horizontal plane and yet exerts a centering effect when the frame has been displaced from its normal position. Small metal damping tubes inserted in the springs damp out any oscillations of the frame.

The enclosure formed by the bowl on the bottom is completed on top by the spider which is fitted with 4 removable transparent covers. The spider provides a mounting for the speed-course correction mechanism and supports the transmitter assembly, follow-up motor, and follow-up coil. To the top of the spider is fastened the follow-up motor and transmitter support casting which in turn carries the driving arm support.

17E5. Sensitive element. The north-seeking portion of the master compass is the sensitive element; (See Figures 17-27 and 17-28.) This unit through gyroscopic action and by virtue of the earth's rotation tends to keep

its axis in the meridian. By means of the follow-up system and

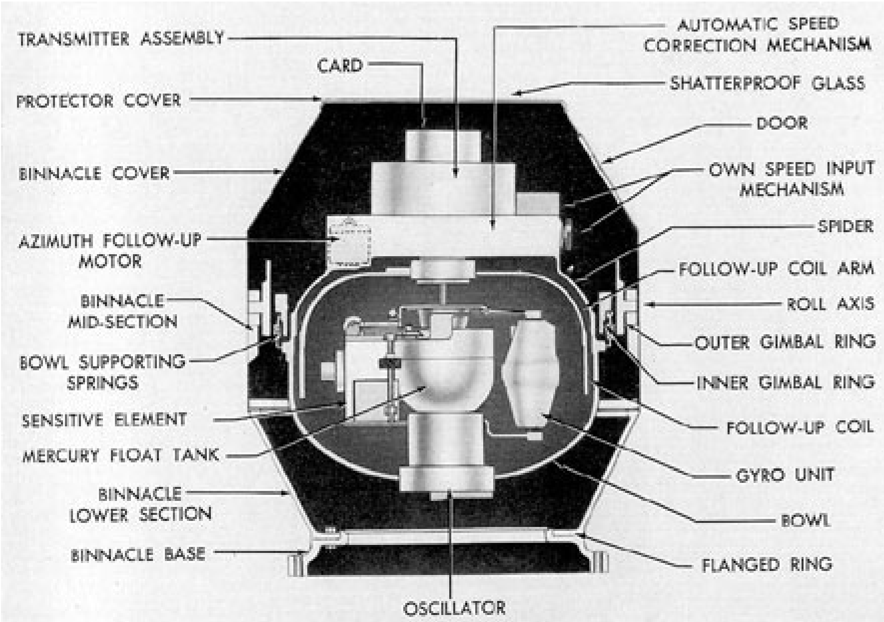

Figure 17-26. Diagrammatiic drawing of master compass.

transmitter, the position of the element controls the reading of repeater compasses throughout the ship. Since the element must be extremely free to turn about any axis, it is supported by a steel ball which floats in mercury.

The sensitive element consists of a frame on which are mounted 2 gyro units and an oil damping device. Each gyro unit is free to rotate about a vertical axis but the 2 units are coupled together by a linkage. On the element are 2 magnets for exciting the follow-up system, and an emergency azimuth scale to be used if the follow-up system should fail.

17E6. Gyro units. Two gyro units provide directive force for the sensitive element; that is, they turn it toward the meridian. One of these units is shown in Figure 17-29.

vertical axis. Around the sight glasses, and other joints, neoprene gaskets are used to make the case airtight.

The gyro wheel and its axle are machined in one piece from alloy steel. Each end of the axle is accurately fitted with ball bearings which are supported inside the gastight casing. One side of the gyro wheel is machined out around the axle to make room for the induction motor windings. The squirrel cage winding is pressed into the gyro wheel. The primary, or stator, projects into the center of the rotor squirrel cage. Leads from the stator are carried through the casing to terminals on the outside for connections to the supply line. Around the periphery of the wheel a spiral groove is turned and enameled black. This groove is observed through a sight glass on the case to determine whether or not the wheel is

The casing of each unit is equipped externally with upper and lower spindles and ball bearings so that it is free to rotate about a rotating in the correct direction when it is started.

The lubrication system consists of an oil sump at the bottom of the casing from which

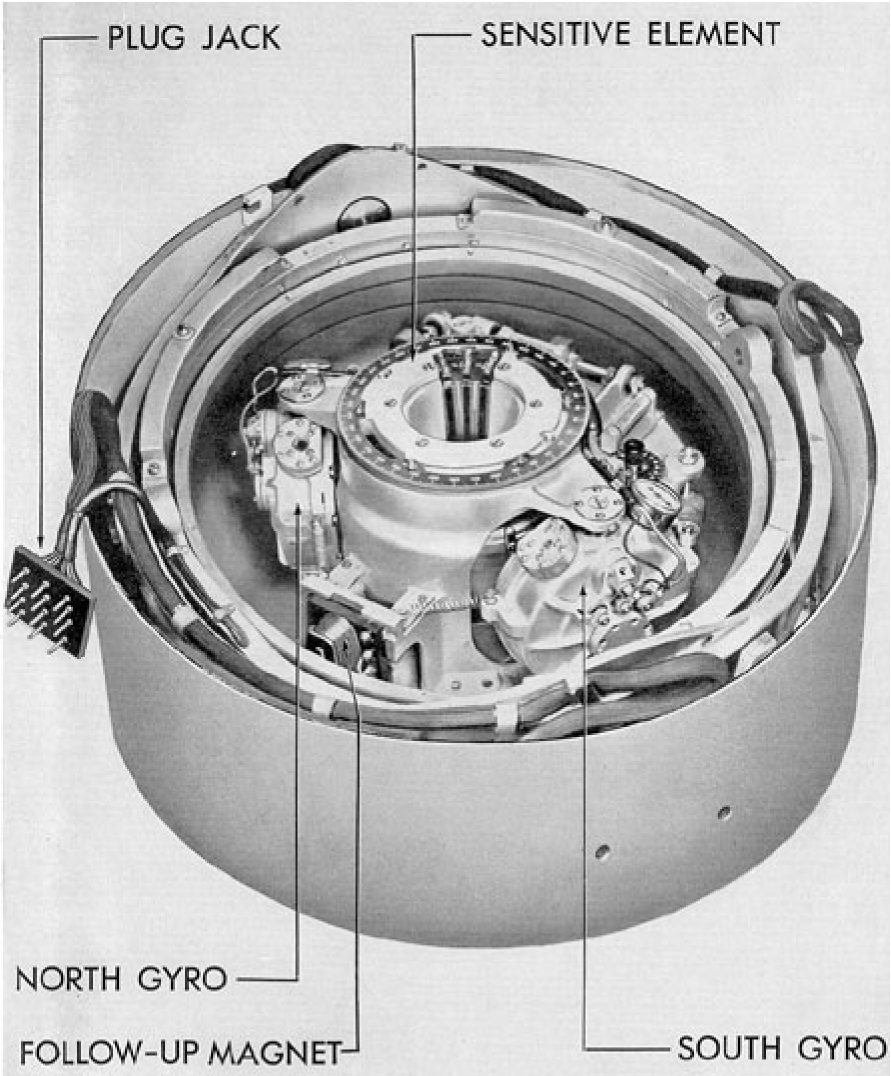

Figure 17-27. Arma master compass, cover and spider removed to show sensitive element.

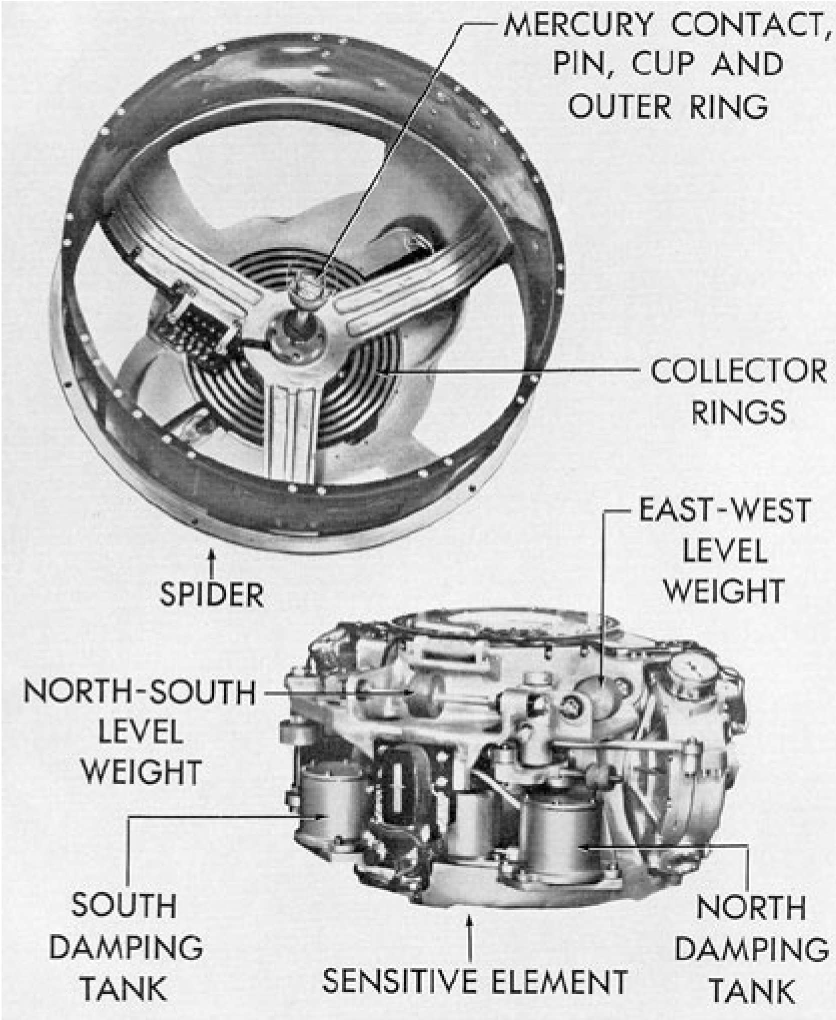

Figure 17-28. Bottom view of spider, sensitive element.

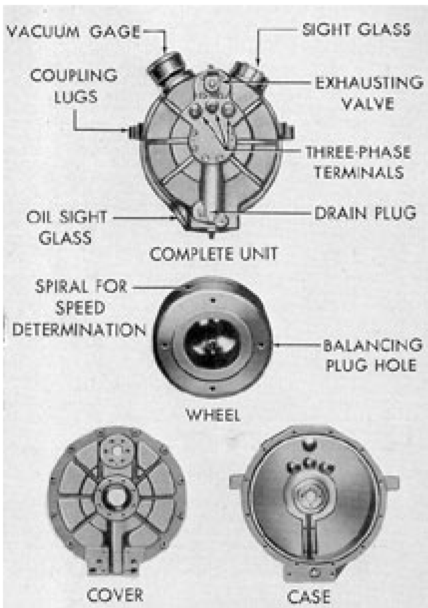

Figure 17-29. Gyro unit, disassembled.

cotton wicks carry the oil up and around each of the axle ball bearings. The oil sump is provided with a drain plug end pipe. (See Figure 17-30.) Were it not for this damping system, the element would continually oscillate back and forth across the meridian instead of settling down into its correct position. The illustration shows the tanks in a sectional view. They are aligned parallel to the meridian and are totally enclosed. The tanks are connected by a pipeline at the bottom for oil, and by another at the top for air. They are filled to a depth of 1 1/4 in.

In order to obtain the proper damping percentage, it is necessary to restrict the flow of oil between the tanks. This is accomplished by means of an

with a circular sight glass to show the oil level, the correct level being at the midpoint of the glass. A high-grade oil that is free from moisture and other volatile substances is used.

A vacuum is maintained within the case to eliminate windage losses, to reduce the heating of the rotor, and to prevent gumming of oil in the bearings. A gage on the unit shows the degree of vacuum and so serves to indicate possible leakage. The casing is fitted with an exhaust valve that is used in evacuating the case. On the north gyro unit, the positions of the vacuum gage and sight glasses are opposite to what they are on the south gyro. Therefore the units are not interchangeable.

17E7. Oil damping system. On the east side of the sensitive element frame are 2 tanks partly filled with oil and connected at the bottom by a obstruction inserted in the pipeline.

To avoid the damping error, it is necessary to nullify the effect of the damping system during changes in course. To prevent the flow of oil due to the accelerating forces present during a turn, a damping cutout valve is placed in the oil line connecting the two damping tanks. This valve operates whenever the change in ship's course is greater than 15 degrees and it is controlled automatically by a pair of contacts in the transmitter assembly. The valve consists of a steel ball, inside the oil line, which can be drawn up vertically against a spherical seat by an external electromagnet when the oil flow is stopped. Thus, the valve is operated without disturbing the equilibrium of the sensitive element.

17E8. Mercury flotation. The directive force of any gyrocompass is small when nearly on the meridian. It is therefore necessary to suspend it in as nearly a frictionless support as possible. This is accomplished by supporting the sensitive element on a hollow steel sphere which floats in a concentric tank of mercury (see Figure 17-31).

The element is constrained from drifting laterally by the center electrical contact pin which fits loosely into a guide at the center of the floating sphere. This pin, together with a pair of concentric contact rings, projects from a shaft which is carried at the center of rotation of the follow-up arms. Thus, there is practically no relative rotation between the contact pin and rings and the sensitive

element. The vertical position of the element is governed by the

quantity of mercury in the tank. The sphere should clear the bottom of the tank by 3/16 in. For convenience in checking this position, a line has been placed on the contact support tube. This line is level with the topmost surface of the sensitive element when the flotation is correct.

17E9. Oscillation mechanism. To eliminate any possible static friction in the mercury

17E10. Follow-up mechanism. a. General. The follow-up mechanism is that part of the master compass that drives the card dials and controls the repeater compass readings without reacting upon the sensitive element. This is accomplished by amplifying a small voltage which is induced in the follow-up coils by magnets on the sensitive element, and using this amplified

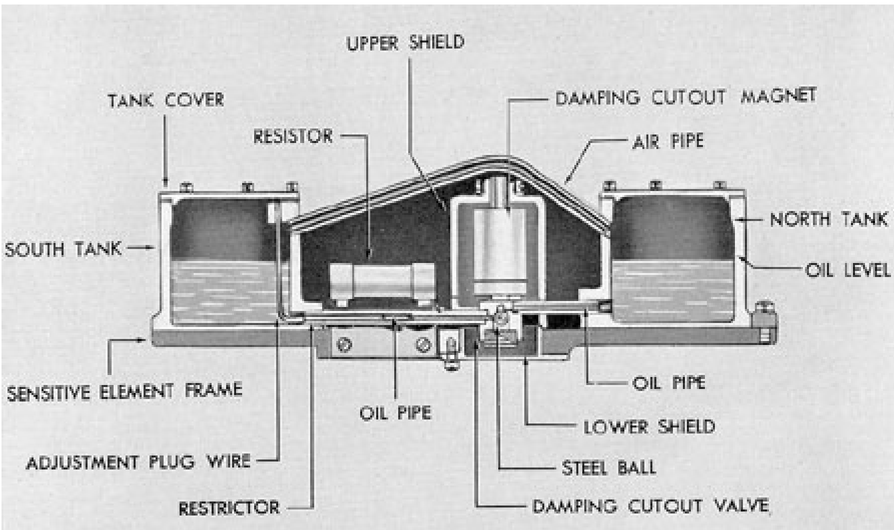

Figure 17-30. Oil damping system.

which would slightly reduce the freedom of the sensitive element, the tank is suspended from leaf springs and caused to oscillate continuously through a small angle several times a second. The oscillating mechanism is located below the tank. (See Figure 17-26.) The mechanism consists of a split-phase motor driving an eccentric and connecting linkage.

voltage to control a motor geared to the card and follow-up coil. The motor operates to keep the follow-up coil and the card in their proper position relative to the sensitive element. The follow-up mechanism is part of the master compass. It is distinguished from the follow-up system that includes the mechanism and the follow-up panel.

b. Speed correction mechanism.

introduced into the multiplier, and

The automatic speed correction mechanism is provided with a synchronous motor which receives an indication of ship's speed from the underwater log, and a follow-up motor which applies this quantity to a lever type multiplier. By means of a manual control which is graduated in degrees of latitude, the secant of the latitude is the resulting product is applied to an eccentric bearing in the correction mechanism. The speed corrector requires manual resetting only for changes in latitude; speed variations are taken care of automatically. Provisions are made for hand setting of the ship's speed when the underwater log is secured.

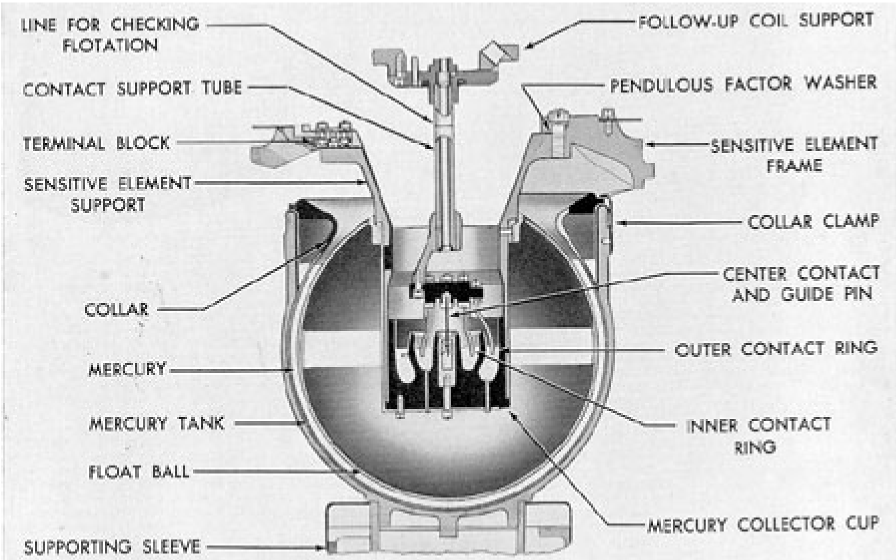

Figure 17-31. Flotation and contact assembly.

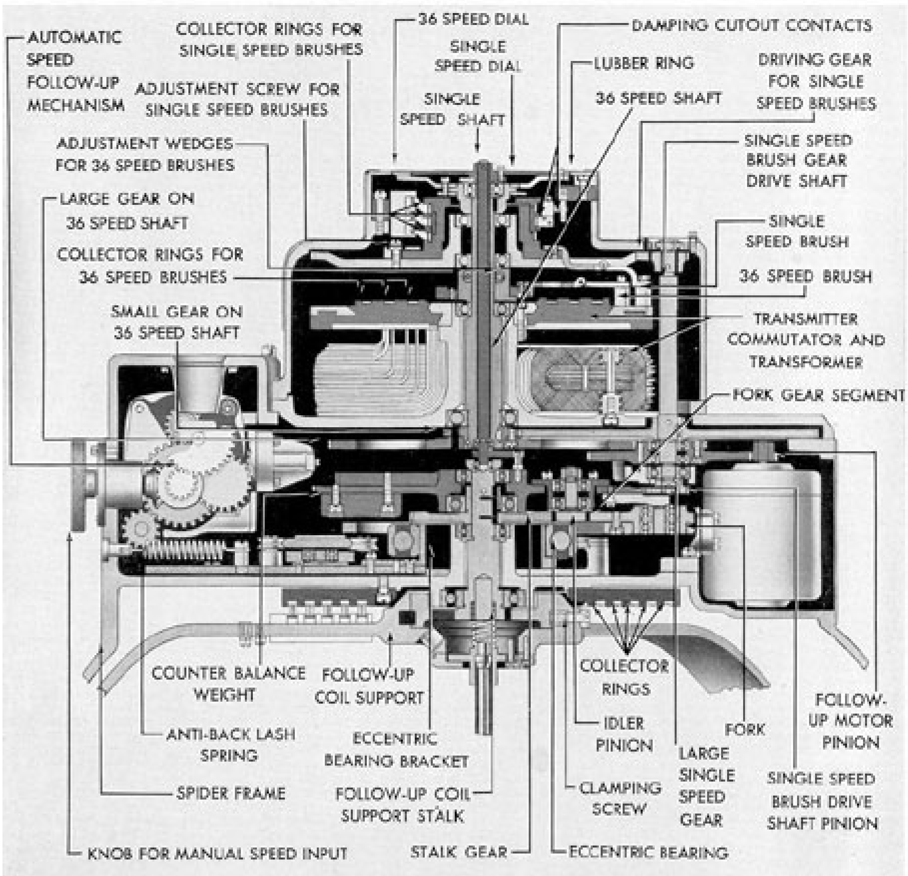

Figure 17-32. Automatic speed correction and driving mechanism.

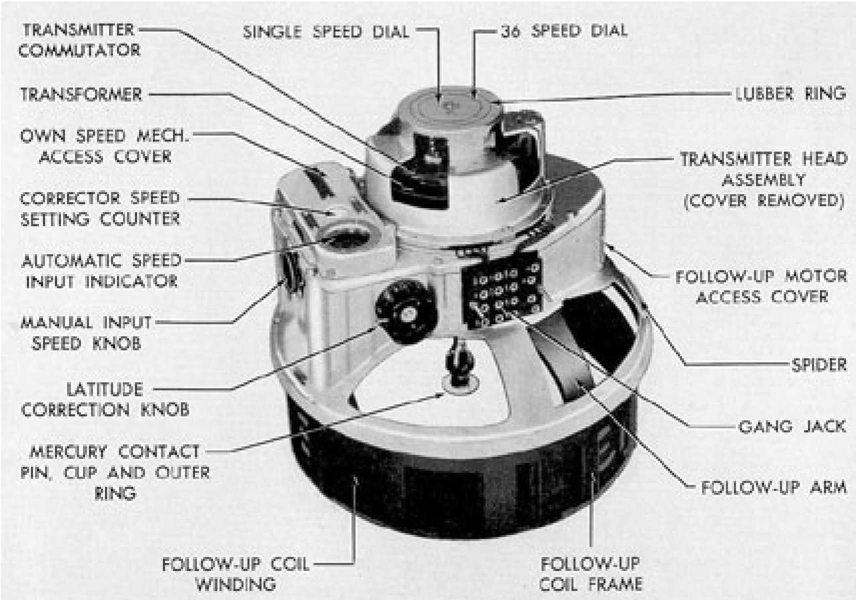

Figure 17-33. Spider assembly.

F. MOTOR GENERATOR

17F1. Function. The motor generator set converts the ship's direct current power supply to a 3-phase supply of variable frequency for driving the gyro wheels.

17F2. Construction. The motor and generator are enclosed in a drip-proof housing. Their rotors are on a shaft which is supported at the frame ends on ball bearings, each bearing being lubricated by a grease cup. The generator is driven by a compound-wound direct-current motor, rated at 115 volts, 3.0 amperes, and 3,000 rpm. Speed control is obtained by means of an external rheostat in the motor field circuit. The motor has been specially designed for good speed regulation so that the effect of variations of the supply voltage on the motor speed has been reduced to a minimum.

Motor generator sets supplied with the various modifications of the master compass are similar in external appearance but vary slightly in capacity. The Mark X Mod. 2, generator is rated at 67.5 volts, 2.0 amperes, and 300 cycles at 3,000 rpm.

When the motor speed is reduced, the generator voltage and frequency are correspondingly reduced. Direct current required to excite the generator field is obtained through the control panel from the ship's supply.

G. CONTROL PANEL

17G1. General. Figure 17-34 shows the repeater, control, and follow-up panels. The control panel is used for controlling the operation of the master compass and for indicating conditions of operation such as current and voltage values.

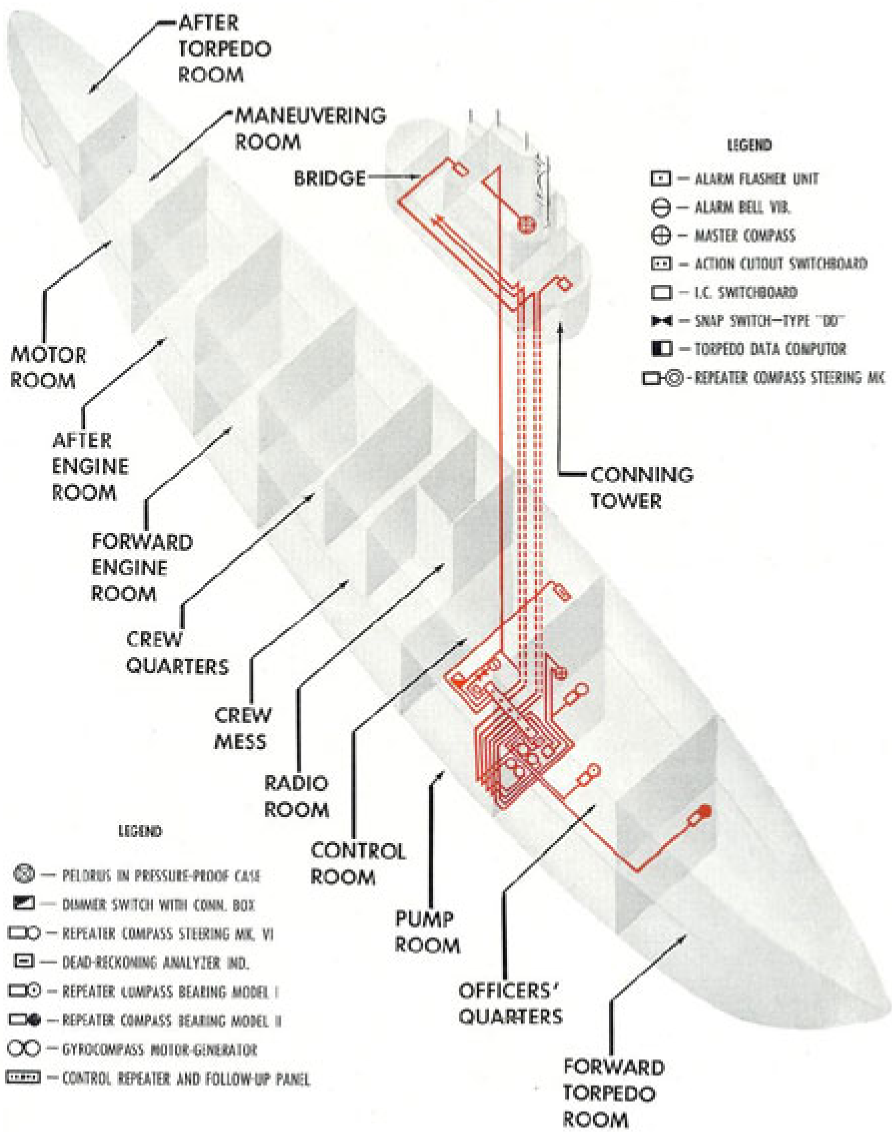

Figure 17-34. Schematic diagram of gyrocompass system.

Connection to motor generators, master compass, and other equipment is made through this panel.

17G2. Instruments. At the top of the control panel are 2 ammeters, 2 voltmeters, and a neon indicator lamp. The lamp serves as an indicator for the voltage and the 60-cycle, single phase a.c. supply voltage.

17G3. Repeaters. Outgoing circuits are provided on late fleet type submarines to repeaters located as follows:

1. forward torpedo room-1 speed

damping cutout and operates when the oil flow system between the damping tanks has been cut off. The 4 instruments indicate:

1. The gyro drive current in each phase.

2. The current drawn by the repeater system.

3. The d.c. supply voltage.

4. The gyro variable frequency supply

2. commanding officer's stateroom-1 speed

3. control room steering station - double dial, concentric 1 and 36 speed

4. conning tower steering station- double dial, concentric 1 and 36 speed

5. bridge pelorus-double dial, concentric 1 and 36 speed with illuminated relative bearing ring

H. OPERATION

17H1. General. The gyrocompass is a sensitive instrument. The first essential in its operation is to see that it is operated by trained personnel only. No attempt should ever be made to disassemble or adjust it. Only qualified gyrocompass repair personnel should ever attempt a major repair or adjustment.

17H2. Starting the master compass. The following procedure should be followed in starting the master compass:

1. The compass should be started about 4 hours before it is required for service.

2. Check the vacuum gage reading of the north and south gyro units. The vacuum should be approximately 29 inches.

3. Check the oil level in the gyro case. The level should be approximately halfway up the sight glass at the bottom of the case. This check may be easily

6. Start the compass and check its operation as described in the manufacturer's instruction book.

7. Read the gyro current in each phase every hour. The current should be about 1.25 to 2.25 amperes. An abnormally high current indicates trouble which should be investigated immediately.

8. Read all voltages and currents every hour. Normal values are as follows:

Gyro drive	1.25 to 2.25 amperes
A.C. single phase	115 volts
A.C. gyro drive voltage	23-68 volts
D.C. voltage	115 volts
Repeater system current	See below

The instrument marked REPEATER SYSTEM CURRENT indicates the current drawn by the transmitter circuit and repeaters. It will read about 5 to 6 amperes when no

made by holding a mirror next to the sight glass and viewing the reflection of the oil level in the mirror.

4. See that all switches on the control and repeater panel are in the OFF position. The damping cutout switch is an exception to this rule and should be in the ON position when the ship is not making way.

5. Have the power supplies to the control panel energized.

repeaters are connected. The reading should increase about 0.6 amperes for each additional synchronous motor added to the load.

17H3. Use of level in settling element or meridian. If it is necessary to put the compass in operation on short notice, considerable time may be saved by precessing the element on to the meridian by hand. Proceed as follows:

1. Start the compass in the usual manner.

2. Determine the approximate ship's heading.

3. Precess the element until the card indicates the ship's heading. This is done by pressing down lightly on the north or south side of the element.

4. Bring the bubble in the north-south level to the center of the scale. To do this press against the end of the bubble tube in the direction the bubble must go.

5. It is impractical to set the compass and

have it remain exactly in its settled position because the damping oil must seek its final level and because temperature changes as the instrument warms up cause slight disturbances.

17H4. Shutting down the compass. To stop the compass, turn all the switches on the control and repeater panels to the OFF Position. No further attention is required. The gyro wheels will continue to rotate for about an hour. Do not attempt any work on the element until the wheels have stopped.

I. CARE AND MAINTENANCE

17I1. Inspection and checks. The gyrocompass requires little attention if operating instructions are carefully followed. Inspection, cleaning, and oiling should be done regularly in accordance with the schedule below. Visual

6. Twice a year. Check the depth of oil in the damping tanks. This should be from 1 1/8 to 1 1/4 inches average value in the 2 tanks. The depth in each tank may be measured by removing the cover. If the average depth is low, add clean oil to bring it to the

inspection may, of course, be made at any time, but as long as the compass is operating satisfactorily, it is best not to perform the other checks more often than indicated by the schedule.

Never shift a weight or make any other adjustment until it is definitely known that trouble exists, and until that trouble has been analyzed.

17I2. Maintenance schedule.

1. Every hour. Check the gyro current and voltages.

2. Every watch. Inspect the vacuum tubes. Make immediate replacement of defective tubes.

3. Once a week. Check the vacuum gage readings. Small changes from previous readings may be due to variations in barometric pressure, but a large change indicates trouble.

Clean the control and repeater panels. Inspect the connections and look for blown fuses.

Clean the motor generator set. Turn down each grease, cup one turn.

4. Once a month. Clean the binnacle inside and out, making certain that no foreign objects have fallen across the terminal blocks in the base.

Clean the bowl and spider.

When the gyro wheels are not rotating, clean the entire sensitive element.

5. Once in 3 months. Put a drop of gyro oil in each gimbal ring correct value. Be very careful to keep out dirt, or any foreign particles.

7. Once every 24 months. Lubricate the synchro bearings if they have not been lubricated in the previous 18 months. Use 1 drop of oil in each bearing.

The upper spider bearings and all gearing should also be lubricated every 24 months, although this is not absolutely necessary.

8. After extended shutdown. Before starting the compass after it has been out of service for some time, all the checks that are made once in 3 months or more often should be gone over. In addition, the transmitter commutator, all collector rings, and the damping cutout contact should be examined and, if necessary, wiped off with a cloth dampened with an approved solvent.

17I3. Compartment pressure test. Before any compartment of the ship is submitted to a 15-pound pressure test, all repeater compasses in the compartment must have the small plug in the lower cover removed to equalize the pressure on the glass. A master compass in the compartment must have the vacuum cocks of both gyro casings opened to equalize the pressure on the casings and to protect the vacuum gages from breakage.

bearing.

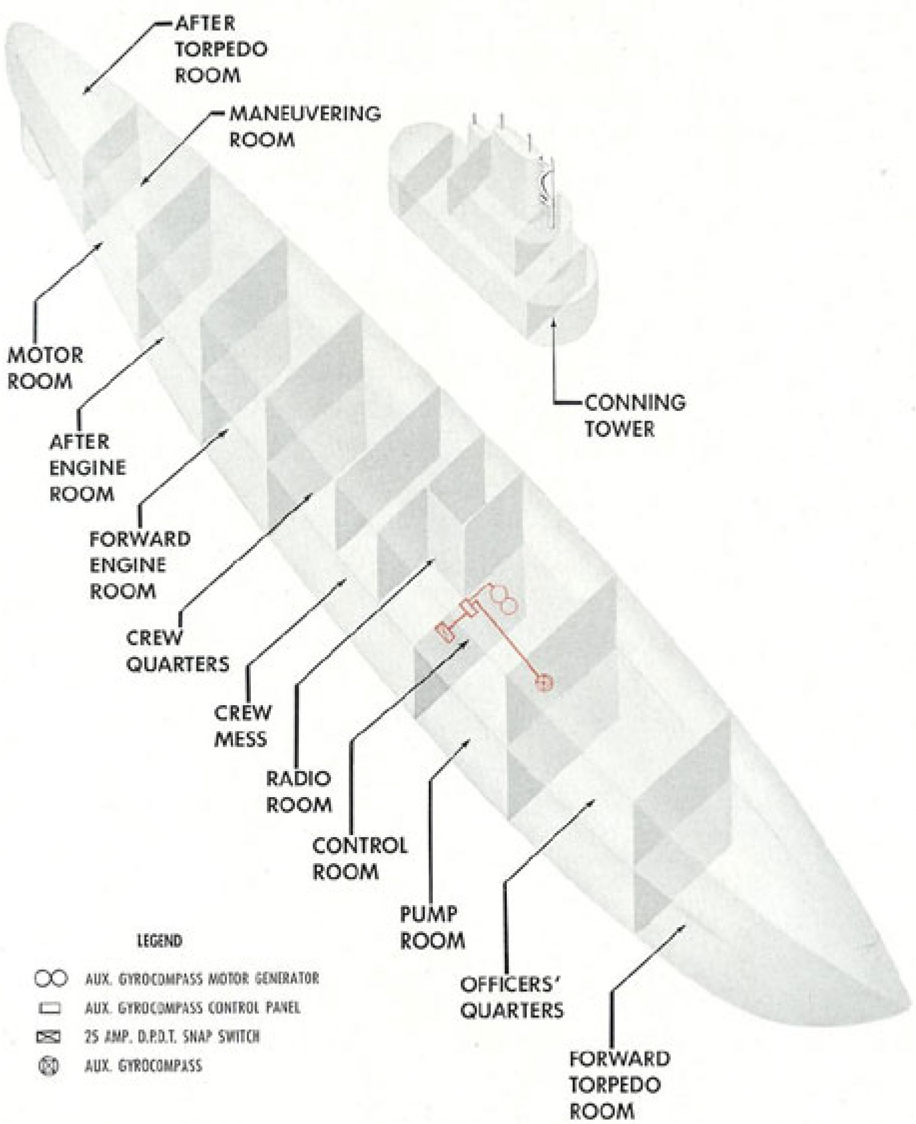

Figure 17-35. Schematic diagram of auxiliary gyrocompass system.

J. AUXILIARY GYROCOMPASS

17J1. Description. a. General. The Arma Mark 9 gyrocompass has been developed as an auxiliary compass for submarines, to indicate accurately the ship's true heading. It is designed primarily for emergency use when the main compass is inoperative. The auxiliary compass is light, compact, simple to operate, and eliminating the intercardinal rolling error. The gyros run at about 18,000 rpm and are supplied with power from a motor generator, driven by the ship's supply. A pair of oil-filled damping tanks, connected by a restricted pipe, are also mounted on the element, level with the center of flotation, so that tilting of the element of gimbal rings will not

readily accessible for maintenance.

The equipment consists of 3 main units, the compass proper, which is enclosed in a binnacle, the motor generator, and the control panel.

b. Compass unit. The compass unit houses the north-seeking sensitive element, which has gyros arranged in such a manner that the rotation of the earth tends to maintain the element

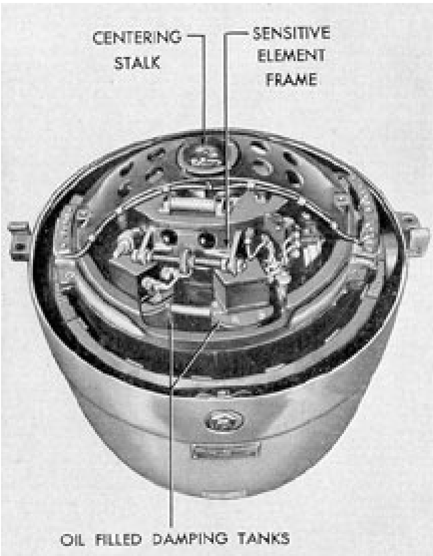

Figure 17-36. Arma auxiliary gyrocompass Mark 9, cover removed.

on the meridian. The sensitive element floats freely in a tank of mercury and carries 2 gyros mounted at an angle of 25 degrees to the meridian. Two wheels are used to stabilize the sensitive element in an east-west direction, thereby cause an apparent change in course. The dial is read through the binnacle cover glass. The element is restrained from drifting sidewise in the mercury by means of a centering stalk, which also provides an almost frictionless method of making an electrical connection to the gyros. The other connection is made through the flotation mercury. The mercury tank is oscillated back and forth through a small angle, several times a second, in order to break up surface friction between the mercury and the pot. The entire inner member containing the pot is pendulous and is spring-mounted in a pair of gimbals. The gimbal pivots are damped by means of felt washers saturated with an

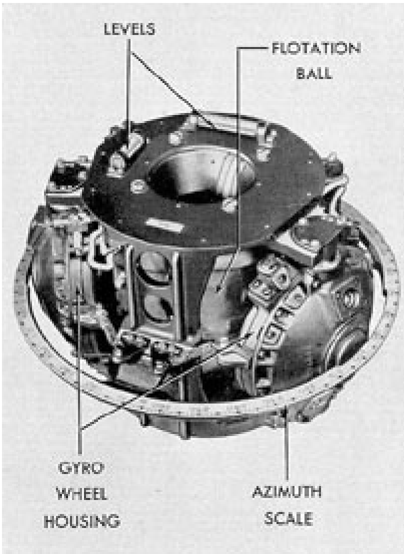

Figure 17-37. Arma auxiliary gyrocompass Mark 9, sensitive element.

extremely viscous oil. Access to the sensitive element is obtained by removing the top portion of the binnacle and the bridge cover over the element.

the gyros. The relay contacts are adjusted to open when the wheels are about up to speed, which requires approximately 10 minutes.

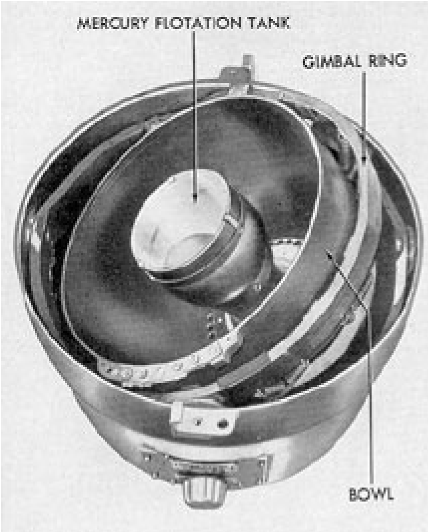

Figure 17-38. Arma auxiliary gyrocompass Mark 9, lower housing, gimbals and mercury flotation tank.

The gyro wheels are driven by squirrel cage, induction motors, whose high frequency supply is furnished by the motor generator. The single phase output of the generator is made 2-phase in effect, by running one side of the line through a condenser network to split the phase. The starting load on the gyro rotors is naturally much higher than the running load. To keep the phase relationship correct for both conditions, one of the condensers is cut out of the circuit when the wheels are nearly up to their normal speed. This is accomplished by a thermal relay mounted on the sensitive element. When the thermal relay is cold, its contacts are open. Its heating element is connected in series with one winding of the gyro motors, and consequently is subjected to the current drawn by

c. Motor generator. The motor generator (Figure 17-39) is designed to operate from 115 volts, d.c., and run at about 3,000 rpm. There are 2 generators in the unit. One, a 120-volt, 300-cycle, single-phase generator is for the gyro supply; the other, a 24-volt, d.c. generator is for operating the oscillator motor and compass lights.

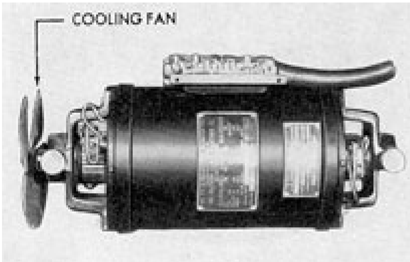

Figure 17-39. Arma auxiliary gyrocompass Mark 9 motor generator set with end covers removed.

d. Control panel. (See Figure 17-40.) One type of control panel is used where the compass power supply is between the limits of 88 to 125 volts d.c. This condition exists on ships in which the compass is run from the 88- to 125-volt lighting bus, which normally is controlled to 115 volts d.c. On other vessels using this panel, the compass normally is supplied from the 115-volt lighting motor generator, with an auxiliary supply from the 88- to 125-volt tap on the main battery, controlled to 115 volts. Here, both normal and auxiliary supplies come over the same leads from the I.C. switchboard. A green pilot lamp is provided to show when the power supply is available.

To insure positive starting of the motor generator, in case the voltage is allowed to drop to 88, a START position is provided on the

motor generator switch. In this position, a

resistance is placed in series with the field of the motor, which is the shunt-wound type, and resistance is cut out of the generator field circuit. This gives sufficient speed and output voltage to start the gyros. The switch should be left in this position for 3 minutes, before being thrown to ON. The compass operates best when the supply voltage is kept within 10 percent of 115 volts.

Figure 17-40. Arma auxiliary gyrocompass Mark 9 control panel.

17J2. Operation. In general, the operating procedures for the auxiliary compass are the same as for the main compass. Detailed instructions may be found in the manufacturer's instruction book.

17J3. Maintenance. Complete instructions for the maintenance of this compass are given in the manufacturer's instruction book which should be consulted prior to servicing the compass.

K. DEAD RECKONING ANALYZING INDICATOR AND TRACER SYSTEMS

17K1. General. The Arma dead reckoning system consists of a Mark 5 Mod. 0 dead reckoning analyzer indicator located in the control room, and a Mark 7 Mod. 1 dead reckoning tracer located in the control room, or in some ships, in the conning tower.

The system, when properly set at the starting point, indicates at all times the latitude and longitude from the underwater log system. In some units, 2 transmitters have been installed in the analyzer indicator for transmitting distance and direction of ship's movement to the dead reckoning tracer motors which drive a pencil over a chart.

17K3. Distance converter. The distance converter is comprised of the distance input motor,

of the ship's position on dials visible through windows in the cover of the analyzer indicator, and traces the ship's movements on a chart placed on the tracer. The total distance traveled by the ship, regardless of its course, is also indicated on the analyzer.

17K2. Analyzer indicator. The analyzer indicator (Figures 17-41, 17-42, and 17-43) is an instrument for converting the ship's course and distance into direct readings of latitude, longitude, and miles traveled. It receives the ship's course from the gyrocompass, and its distance, energized by the underwater log distance transmitter, and the gearing that connects the motor to the component carriages.

These carriages are mounted in guide rollers to permit vertical motion which determines the position of a friction disk and consequently the speed of the gear train.

Crank arms, controlled by the input from the gyrocompass, position the carriages vertically. By their movement, the ship's travel, through the rotation of 2 disks, is resolved into

components in a north-south and east-west direction. Through an arrangement of gears and disks, the motions of the disks are transmitted to longitude and latitude dials and drive the dead reckoning tracer transmitters. Arrangement is made for shifting the latitude mechanism for either north or south operation when the equator is crossed. Likewise, the longitude mechanism must be shifted when crossing 0 or 180 degrees longitude.

17K4. Dead reckoning tracer. The tracer is enclosed in a metal box with hinged glass cover (Figure 17-44). The principal parts of the tracer mechanism include the cross screw motor which drives the tracing pencil in an east-west direction across the chart by rotating the cross screw. The north-south motion of the pencil is derived from the lead screw motor which, through a screw shaft and nut, moves the cross screw, pencil, and support arms in a north-south direction.

To permit the use of the tracer on differently scaled charts, the speed of the cross screw and lead screw can be regulated by means of the friction disks between the drive motors and screw shafts. This setting is made by turning the handwheels to the scale of the chart being used. These handwheels are located outside the tracer box and are designated as scale selectors. Switches are provided to stop and start the screw motors. Illumination is controlled by means of a rheostat. Pilot lamps indicate when the mechanism has reached the end of the screw shafts. The initial starting point of the pencil is set by means of hand cranks.

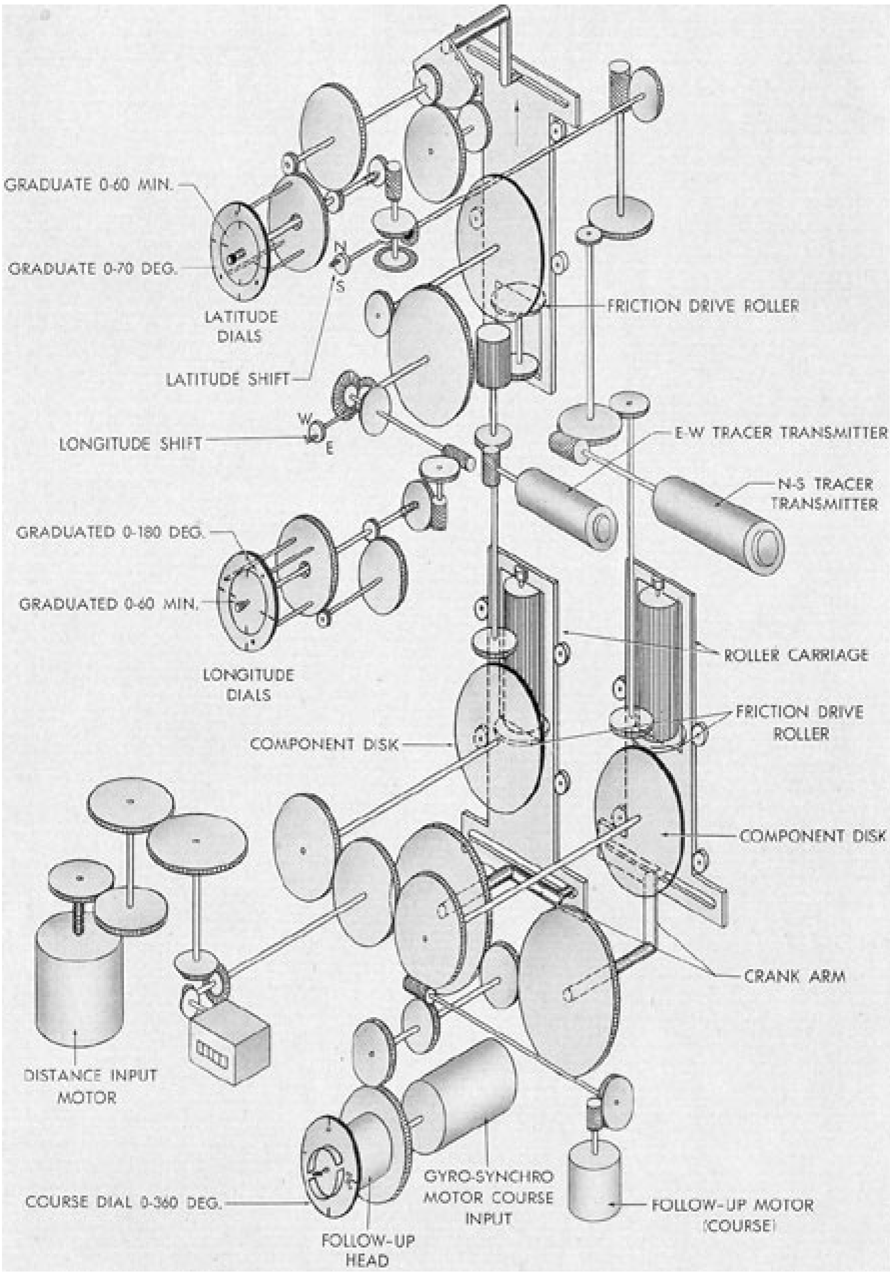

Figure 17-41. Dead reckoning analyzer Indicator gear diagram.

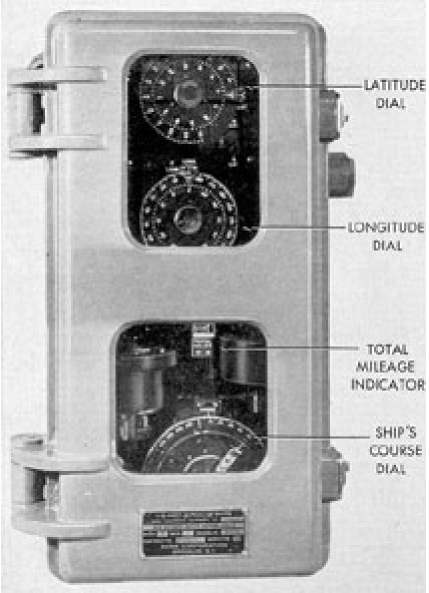

Figure 17-42. Dead reckoning analyzer indicator.

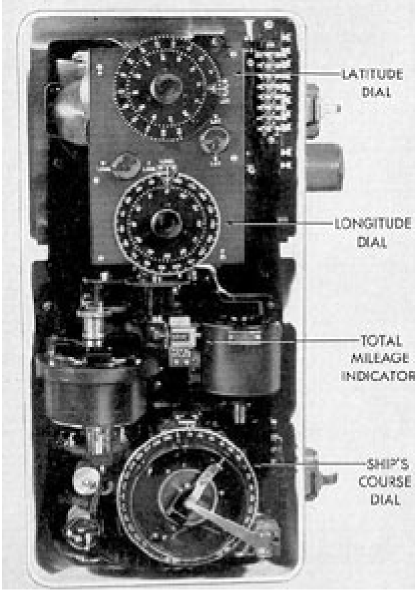

Figure 17-43. Dead reckoning analyzer Indicator with cover open.

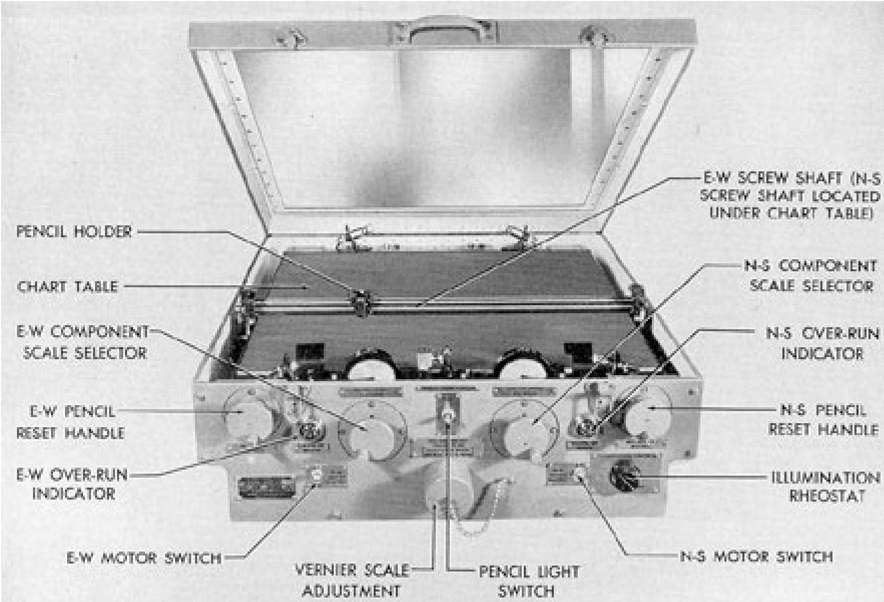

Figure 17-44. Dead reckoning tracer with cover raised.

18
MEGGERS, AMMETERS, AND VOLTMETERS

A. MEGGERS

18A1. Description. A megger is an ohmmeter-type instrument by means of which the value of a resistance can be measured and directly indicated by the position of a pointer on a scale. The resistance indicated in an ohmmeter-type instrument is independent of the voltage applied for a test. The megger consists of two principal elements: a hand-driven magneto type direct current generator, which supplies the current for making the measurement; and the moving element with pointer, by means of which the value of the resistance under measurement is indicated.

Figures 18-1 and 18-2 illustrate the construction of the moving element and the magnetic circuit and electrical connections in the instrument. The permanent magnets serve for both the ohmmeter and the generator. The armature of the generator is hand-driven. The rotational speed is stepped up through gears and maintained at a constant rate, if a certain cranking speed is exceeded, by means of a clutching mechanism. The type III instrument generates 500 volts and has a scale of 0 to 100 megohms.

over the scale. Hence, when the generator is not being operated, the pointer may stand in any position over the scale.

When current flows in coils A and B, they tend to turn the moving element in opposite directions. The pointer then takes a position over the scale where the two forces are equal.

When the instrument is operated, either with perfect insulation, or with nothing at all connected across the earth and line terminals, no current flows in coil A. The potential coil B alone controls the movement and takes a position opposite the gap in the C-shaped core, and the pointer indicates infinity.

When, however, a resistance is connected across the terminals, a current flows in coil A and the corresponding torque draws the potential coil B away from the infinity position into a field of gradually increasing magnetic strength until a balance is obtained between the forces acting on the respective coils. Hence, by introducing resistances of different known values across the terminals and marking the corresponding position of the pointer in each case, a scale

18A2. Principle of operation. The instrument system consists primarily of two coils, A and B (Figure 18-1), mounted on the same moving element, with pointer attached, in a permanent magnet field, Coil A is connected in series with a resistance between the negative side of the generator and the line terminal, and is called the current coil. Coil B, in series with another resistance, is connected across the generator terminals, and is called the potential coil.

The moving element is mounted in spring-supported jewel bearings and is free to rotate about its axis, since there are no restraining or controlling springs such as there are in an ammeter or voltmeter. Current is led to the coils by flexible conducting ligaments having the least possible torsion, so that the pointer floats calibrated in resistance can be obtained.

Since changes in voltage affect both coils A and B in the same proportion, the position of the moving element is independent of the voltage. In the event that the instrument is short circuited, the ballast resistance is sufficient to protect the current coil.

The resistance range of meggers is very great. For insulation resistance measurements, their range is in thousands of megohms. They are also designed to measure a resistance of only a few ohms, such as the resistance to ground of tower footings or ground wires. In service, the megger is used for measuring insulation resistance of cables, insulators, and windings of motors and generators.

To prevent the demagnetization of the

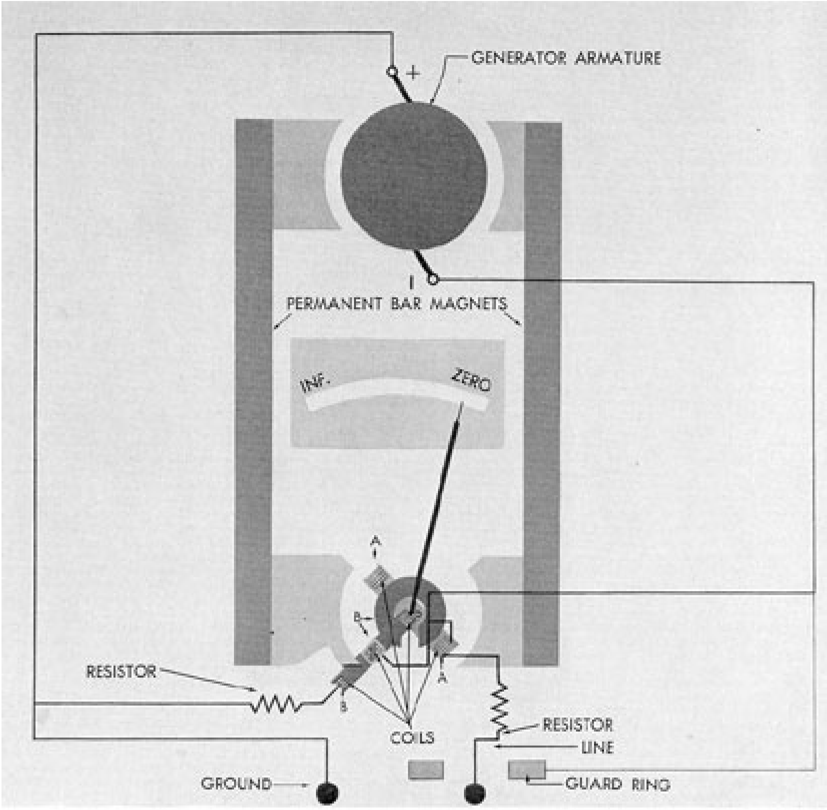

Figure 18-1. Megger magnetic circuit and electrical connections.

permanent magnets, a megger should never be connected to a circuit in which current is flowing and should not be placed on a pole piece or the bedplate of a motor or generator.

18A3. Maintenance. The megger should be given the same care and consideration as any delicate instrument, as it contains a moving coil with steel pivots turning in jewels and can be injured by rough handling. There is an insulating guard ring around each terminal post which is wired to an internal circuit. This serves to bypass around the moving coil element any leakage current which may pass across the moist or dirty surfaces of the box and which would otherwise give an incorrect reading of the circuit under test. The guard ring should be maintained intact.

Care should be taken to keep the terminals and terminal posts clean and the leads from being partly broken, as such conditions would add resistance to the circuit and give incorrect readings.

There are no provisions for oiling any of the bearings in the megger from the outside of the case. The original assembly provides sufficient lubrication for several years of use.

The megger has no external adjustments. It can be checked for accuracy by shorting the

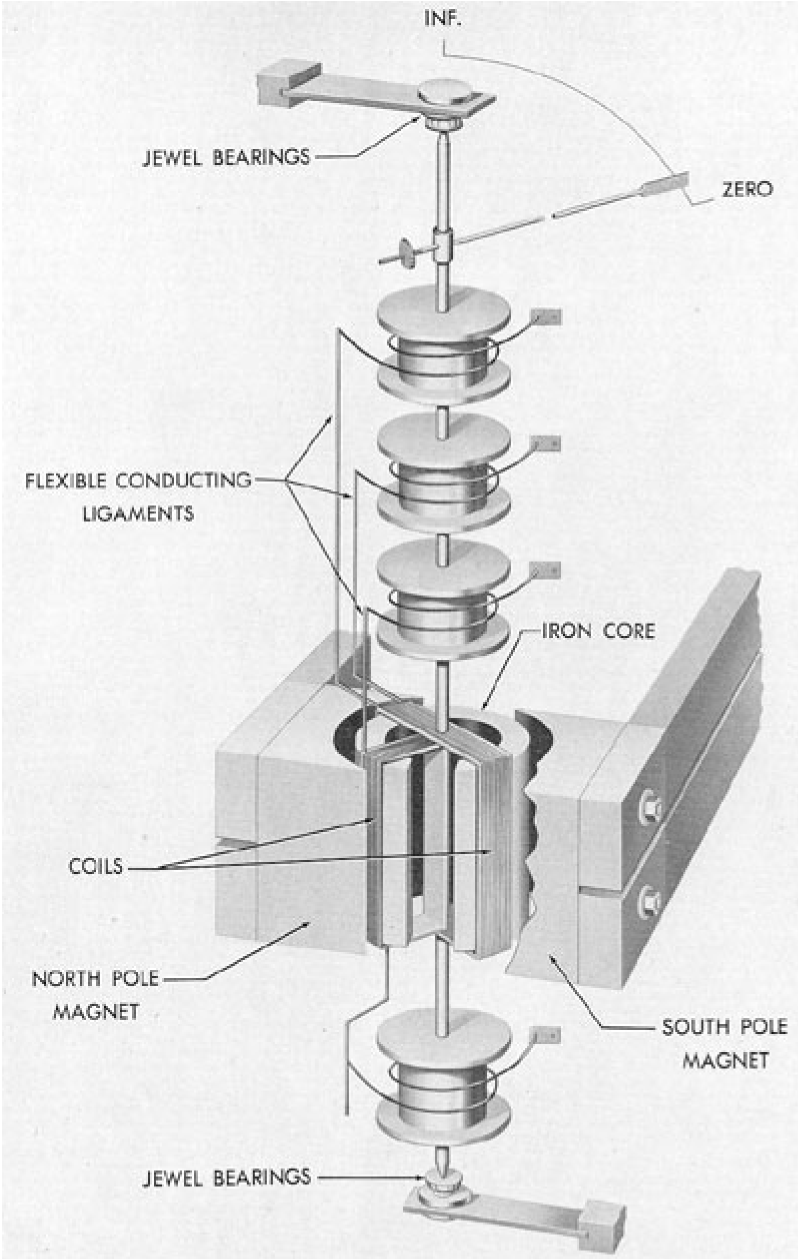

Figure 18-2. Megger moving element.

terminals, when it should read zero. With terminals open, the pointer should stand at infinity when the handle is turned at the usual speed. Intermediate points of the scale can be checked by measuring a known resistance, such as a voltmeter of high range. Weston model No. 24 voltmeter averages a resistance of about 100 ohms per volt. The voltmeter should indicate about 160 volts at 120 rpm of the handle. A falling off of the voltage generated does not

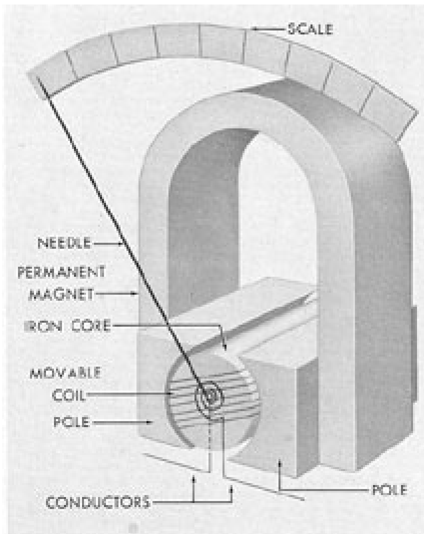

Figure 18-3. Operating principle of direct current instruments.

affect the accuracy of the megger, as the results are independent of the test electromotive force. This means that even though the permanent magnets should change, or the speed of the turning vary, the accuracy remains unaffected. However, if the pointer stands at zero or infinity, as stated above, the megger can be considered as being fairly accurate. The pointer may stand anywhere on the scale when the instrument is idle.

Repairs of any kind should be undertaken only by an instrument maker who understands the theory of operation, as the circuit resistances have a certain relationship which must be maintained.

B. AMMETERS AND VOLTMETERS

18B1. Description. The ammeters and voltmeters supplied as part of the ship's measuring instruments are direct current instruments. Direct current instruments are fundamentally current measuring devices and their indications or calibration depend upon the characteristics of the meter.

Ammeters and voltmeters are alike in construction except for the fact that the coil of the ammeter is wound with fewer turns of coarser wire than the coil of the voltmeter. Thus the coil of the ammeter is of lower resistance than the coil of the voltmeter.

A coil with steel pivots and turning in jewel bearings is by the reaction between the permanent magnet field and the field resulting from the current flowing through the moving coil that causes deflection and gives an indication of the current or voltage being measured. An instrument of this kind measures direct currents only.

18B2. Operating principle of direct current instruments. If the moving coil of an ammeter carries a current, a magnetic field results with a north and a south pole at opposite ends of the coil. If the coil carrying the current were placed in a magnetic field, the coil would tend to turn in such a direction that the resulting magnetic field due to both the main field and that of the coil would be at a maximum. Also the

mounted in a magnetic field which is produced by permanent magnets. Motion of the coil is restrained by two small flat coiled springs which also serve to conduct the current to the coil. The deflections of the coil are read with a lightweight pointer which is attached to the coil and moves over a graduated scale.

It is the force set up in the moving element north pole of the coil would be attracted toward the south pole of the magnet, and the south pole of the coil would be attracted to the north pole of the magnet.

The moving coil of a direct current instrument is made of several turns of wire carefully insulated and wound upon a rectangular

aluminum frame. This coil is supported at the top and bottom by hardened steel pivots turning in cup-shaped jewels, usually sapphires. This method of supporting the moving coil is almost frictionless. The current is led in and out of the coil by two flat spiral springs, one at the top of the coil and the other at the bottom. These springs also serve as the means of measuring the force exerted by the current through the moving coil and cause the pointer to return to zero when current ceases to flow.

When current flows through the moving coil, it rotates to a position where the force due to the field of the coil is just equal to the returning force of the springs. The top and the bottom springs are coiled in opposite directions so that the effect of change of temperature, which causes a spiral spring to coil or uncoil, does not cause the needle to leave its zero position. A light, delicate, aluminum pointer is attached to the moving element to indicate the does proper damping give faster readings, but these slight oscillating swings serve to assure the user of the instrument that there is no frictional lag present.

From the foregoing we have learned that the deflection of a direct current instrument is a measure of the current passing through it. The field of the moving coil tends to rotate the coil to include as much of the flux from the permanent magnet as possible. This motion is opposed by the phosphor-bronze springs.

18B3. Operation of ammeters and voltmeters. An ammeter, or the external ammeter shunt, if there is one, is always placed in series with the line, while voltmeters are placed in shunt across the line. If the ammeter is used with an external shunt, the shunt should have the same serial number as the instrument, and the calibrated leads, considered a part of the instrument and furnished with it, should always be used to connect the instrument to the shunt. Ammeters ranging up to 50

deflection of the coil. This is carefully balanced by small counterweights so that the whole moving element holds its zero position very closely, even if the instrument is not level. The pointer moves over a graduated scale, marked in volts or amperes as the case may be. Because of the uniform radial field, the deflection of the moving coil in this type of instrument is practically proportional to the current in the moving coil with the result that the scale of the instrument has substantially uniform graduations.

If the moving coil, which is mounted on jeweled bearings, starts to swing, it continues swinging back and forth for some time, unless it is in some way retarded or damped. One method of damping is to attach an air vane to the coil. This air vane is enclosed so that it swings in a restricted space and damps any swinging movement of the coil. The most satisfactory method is electrical damping. If the coil is wound on an aluminum bobbin, the motion of the bobbin through the magnetic field induces magnetic currents within itself in such a direction as to put an electric load on the moving coil. This opposes the motion of the coil and thus brings the pointer to rest at the value to be read. The pointer of a properly damped instrument moves quickly and comes to rest with only about two or three overswings. Not only amperes have self-contained shunts, while ammeters for over 50 amperes usually have separate or external shunts. Special care should be taken to see that all contacts are clean, well-made and tight.

CAUTION. An ammeter should never be connected across the line. Such a connection would destroy the instrument.

18B4. Maintenance. Instruments should always be carefully handled and any shock or vibration avoided. In use, they should not be placed in close proximity to any current-carrying conductor or magnetic field. If more than one instrument is used, they should be placed at least 6 inches apart, to avoid mutual magnetic effects. If the pointer does not read zero when the current is off, use the zero adjuster to bring the pointer to zero. By a quick side shift of the instrument, it can readily be determined whether the pointer or moving element is free from unusual friction, and by turning about an axis of rotation, whether it is out of balance.

The instruments require no oiling at any time. The covers should always be kept free from dust and dirt and the screws tightened down to prevent dust from getting inside to the

working parts. The instruments at all times should be carefully handled and kept in a dry, clean locker under the charge of a responsible man. Note that the instruments are sealed when received. When the instruments have been repaired, the seals should be renewed so that tampering with the instrument can be detected.

Repairs and adjustments can readily be made by a competent instrument man, but owing to the fact that the instruments them selves are used as the working or secondary standards on shipboard, there is usually no instrument of similar range available for checking or calibrating them. For this reason, when an instrument needs repairing or when there is any doubt as to accuracy, it should be calibrated by a tender that is equipped for this work, and if that is impracticable it should be sent to a navy yard for necessary repairs and calibration. Likewise, after repairs or replacement of any parts, a check must be made with a secondary standard instrument and any adjustments necessary to bring the meter within its guaranteed accuracy should be made It should then be sealed by the expert and returned to the vessel from which it was received. Important secondary standard instruments should be checked as a regular routine at frequent intervals whenever primary standards are available.

C. MILLIVOLTMETERS

18C1. Description. Ammeters and voltmeters that are actuated by a few thousandths of a volt are called millivoltmeters.

Millivoltmeters can be used as ammeters by using a shunt across the coil. This shunt makes it possible for the millivoltmeter to carry and indicate a moderately large current. Only a small fraction of the main current flows through the moving coil.

Millivoltmeters can be used for measuring voltage by placing a high resistance in series with the moving coil. A high resistance connected thus in series is generally known as a multiplier.

19
INTERIOR COMMUNICATION SYSTEM MAINTENANCE

A. PRECAUTIONS, MAINTENANCE OF CIRCUITS, INSPECTIONS, TROUBLE SHOOTING, AND REPAIRS

19A1. Precautions. A live wire always carries potential danger if it is not handled properly. Accidents can be prevented if the following precautions are observed:

1. A circuit should be disconnected before starting work on it.

2. A test lamp or other suitable device, depending on the maximum voltage that may be encountered, should be used to determine whether or not a circuit is alive.

3. A tool with a metal handle should never be used unless the handle is insulated with tape.

4. Only one hand should be used when working on a circuit that is alive.

5. Electrical machinery should not be started after an overhaul until an inspection has been made for loose bolts, improper clearance, tools adrift, and so forth. The speed of the machine after starting and also the ammeter readings of field and armature current, should be checked with the instruction books.

to the safety of the ship and they should therefore be given particular attention. All A-1 circuits should be in operation or available for operation 24 hours a day. Tests and inspections should be limited to isolated parts of the circuit, if possible. Parts of all circuits can be isolated or deenergized for tests or repairs without making the complete system inoperative.

19A3. Selsyn maintenance. See Section 10B2, on selsyn maintenance.

19A4. Keeping circuits in operation. All interior communication and fire control circuits should be energized and operated in all positions and from each control at least once each week.

19A5. Inspecting control units. Operation of interior communication and fire control units such as telephones, jack boxes, contact makers, transmitters, indicators, relays, bells, buzzers, horns, and sirens should be checked once each week.

19A6. Inspecting connections. The wiring and electrical connections of all interior

6. Any conditions causing sparking should be examined and rectified at once.

7. Inflammable liquids must not be used about electrical machinery as a spark might cause ignition.

8. Emery cloth must never be used on electrical machinery. Use sandpaper, but sparingly, and only when absolutely necessary.

9. All protective devices for electrical machinery panels, circuits, and so forth, such as fuses, circuit breakers, no voltage and overload releases, and the like, must be kept in proper working order and at their designated settings at all times.

19A2. Maintenance of class A-1 circuits. Class A-1 circuits are those considered essential

communication and fire control switchboards should be inspected once each month.

19A7. Over-all inspection. An over-all check should be made when operating conditions show it to be necessary, or at least every 18 months. The following steps constitute an over-all check: Deenergize each switchboard; check all bolted connections for cleanliness and tightness; inspect individual leads for chafing; clean bus bars; check securing bolts; remove any dust or lint; calibrate motors; overhaul trouble indicators; tighten all contacts, using new lock or shakeproof washers wherever possible.

19A8. Inspection before getting underway. Telegraph indicator and communication circuits that are to be used while getting underway or standing by should be tested at least an hour before the time designated for getting underway. These circuits are, in general, the class A-2 circuits.

19A9. Trouble shooting. It is not difficult to maintain circuits in operating condition if defects are located and remedied as soon as possible. If this is not done, more serious troubles are liable to result. For example, a single ground may have little effect on the operation of a motor, but if it is not removed,

exposed to water leaks may also suffer from grounds. Grounds are often caused by defects that develop in the insulation. Under some conditions, insulating materials deteriorate very rapidly, and they are subject also to mechanical injury. Some of the more common causes of such defects are:

1. Excessive heat, due to the overloading of the circuit.

2. Excessive moisture, which causes insulation to deteriorate.

3. Oil and grease, which seriously affect rubber and other insulating materials.

there is danger that a second ground will occur and produce a short circuit.

It is necessary to become proficient in testing a circuit and locating the exact spot at which any trouble occurs, without an undue waste of time spent in guessing or in unsystematic searching.

19A10. Grounds, shorts, and open circuits. Trouble in electrical circuits is due to three major causes: grounds, short circuits, and open circuits.

When trouble occurs in a circuit, it is possible, in most cases, to tell at once which of these major causes is responsible. Knowing this, it is not too difficult to make a search and find the exact location of the trouble.

19A11. Grounds and their causes. Grounds occur when current leaks from a conductor to some part not intended to carry current. The most common cause of grounds is moisture. All circuits and their appliances are designed to be watertight, but there may be defects in their construction or in the method of installing them. To prevent grounds due to moisture, all gaskets should be kept in good condition and the covers well secured. All caps on the receptacles should be properly replaced. This applies especially to fire control telephone and signal circuits. Cables that lead outside the pressure hull are especially subject to grounds from leakage due to submerging. Often, sweating may occur inside the junction or

4. Acid fumes, paints, rust, and so forth, which cause chemical decomposition of insulation.

5. Mechanical injuries, caused by making sharp bends, kinking the wire, dragging it over decks or through holes, or striking it while handling stores.

19A12. Short circuits. Short circuits occur when the legs of a circuit come into direct contact with each other, or when some low-resistance path is established between them, thereby allowing an abnormally large current to flow. Short circuits are usually indicated by the melting of the circuit fuse, and as each branch circuit is protected with a fuse, the trouble usually is not difficult to locate.

A short circuit may be caused by two grounds occurring on opposite legs of a circuit. Any of the causes of grounds may also be the cause of a short circuit. Short circuits not due to grounds are usually caused by faulty work, or carelessness on the part of the electrician. The most common of these defects in workmanship are the failure to make proper connections in a box, and leaving parts of the conductor exposed. Sometimes a strain on the wire outside the box may cause a short circuit when plugging into a box that is not fiber bushed. Switches are located on all receptacle boxes, and they should be turned off before plugging in or removing a portable connection.

19A13. Open circuits. Open circuits occur when fuses blow or when circuit breakers open,

distribution boxes and these parts must be looked after periodically. Circuits

due to overloads. These overloads are usually caused by grounds or short circuits and they must be located and corrected. Open circuits may also be caused by such defects as poor connections due to improper securing, dirty connections, or missing screws. Just enough pressure must be used to make certain that connections are tight without stripping threads. Broken connections are also likely to occur when connections are made by twisting wire or strands into loops. This is not a good practice and should not be resorted to except in an emergency connection when it is to be replaced with properly soldered lugs.

19A14. Daily ground test. The electrical installation of a ship requires constant care to keep it free from grounds. A daily ground test is required. In conducting this test, the ship as a whole is first tested for grounds, and if this test indicates the existence of grounds, each circuit is then tested separately. The test is conducted by means of the ground detector on the main control panel switchboard (see Section 3C4).

19A15. Locating grounds. When the daily ground test indicates that grounds exist on any circuit, this circuit should be checked at once and the trouble

1. Disconnect the appliance; open the circuit before beginning repairs, thus avoiding short circuits or further trouble with tools or equipment.

2. Clean all electrical contact surfaces properly.

3. Make tight connections.

4. Tape up the exposed part of the conductor after making the connections, thereby avoiding probable sources of grounds and short circuits.

5. In making wire splices, allow sufficient wire to get enough turns for a strong splice, and trim down the ends of the wire after splicing. Never allow the end of the wire to project in an exposed position.

6. Use rubber tape, then friction tape, and a coat of insulating compound on a wire splice. All three are necessary for good insulation.

7. Properly dry boxes or other electrical appliances, and avoid moisture which might cause corrosion and further grounds.

8. Replace covers on containers so that the closure is watertight. Any water allowed to get in will cause trouble.

9. Do not start work on an appliance whose principle of operation is not known to you. Familiarize yourself with the

corrected. Each circuit is split into sections by means of junction and distribution boxes. To locate the defective part of the circuit, it is necessary to break connections between each section.

Each leg of the section is then tested with a megger, and the section affected is soon detested. Next, the electrical appliances on this section are disconnected. The appliances are then reconnected one at a time and a test made until the affected appliances are found and the defect corrected. Most troubles can be definitely located, or at least located on a certain branch, in this way. Thus, the entire circuit will not have to be gone over completely.

19A16. Repairing circuits and appliances. Efficiency in making repairs to electrical circuits and appliances comes with practical experience and knowledge of electrical principles. In making repairs on electrical circuits, the following precautions should be observed:

appliance by referring to the manufacturer's instruction book.

10. Never place tools on top of bare electrical conductors or terminals. If this happens and the tools are forgotten, serious damage will result when the circuit is closed.

11. Do not overfuse. Such a procedure results in improper protection of appliances on that branch of the circuit.

12. Always plan the work to be done before starting on a job. If this is not done, there is a possibility of ruining valuable tools and causing further trouble. Every repair job, especially if it is an unusual type of job, should be sketched out first and the voltages, currents, connection of instruments, and so forth, carefully worked out and checked. Start repairs only when thoroughly familiar with every detail.

An hours study before the job is started may save many hours and many dollars in the final outcome.

13. Never install extra lights or fixtures or make alterations in any electrical circuit without permission from the electrical officer. The regulations are very clear on this point. Approval of the Bureau of Ships is required before any major alterations may

other fields will lessen the magnetism of the permanent magnets and ruin the instrument. Jarring will often injure the sensitive moving coils.

18. Be careful in connecting ammeters and voltmeters. This applies particularly to ammeters, whose resistance is small. They will burn up immediately if placed across a line.

be made. Protect yourself, your department, and possibly the safety of the ship by not making alterations unless they are properly authorized.

14. Never work on any electrical circuit with which you are not thoroughly familiar, except under proper supervision.

15. The higher the potential of a circuit, the greater the care necessary when working on that circuit. Always take power off the particular part of the circuit on which you are working. Under certain conditions 120 volts is sufficient to cause death.

16. In replacing fuses, always stand on some insulating material such as a rubber mat, a dry board, or dry paper, and always use a fuse holder made of insulating material.

17. Always handle measuring and testing instruments with care. Almost all instruments contain permanent magnets and must not be handled roughly or exposed to strong magnetic fields or vibration. Jars, heat, and proximity to

19. The only safe rule in connecting up a circuit is to first make a sketch of it. Compute the current that will flow and indicate the instrument necessary to make up this circuit, showing how each should be connected. The division officer, or one of his assistants, should check this sketch upon its completion. No errors will be made if proper planning precedes the actual work.

20. Before closing a motor switch, see that the armature resistance is in. Stop the motor by pulling the line switch. Never allow the motor to run if it heats up to an excessive temperature, if it sparks excessively, or if it shows other signs of faulty operation.

21. Defects in the circuits should be repaired as soon as they are discovered. It is much easier to keep the electrical equipment running perfectly by testing it daily, making repairs where needed, than it is to allow existing conditions to become gradually worse until a complete overhaul is necessary.

20
APPENDIX

A. INTERIOR COMMUNICATION CIRCUITS

Circuit Designation	Circuit Name	Circuit Designation	Circuit Name
Class A-1 Circuits, Continuously Energized			
CA	Collision alarm system	LC	Gyrocompass system
EC	Low-pressure lubricating oil and high-temperature circulating water alarm system	X1LC	Auxiliary gyrocompass system
G	General alarm system	1MC	General announcing system
E	Telephone call system	7MC	Submarine control announcing system
Class A-2 Circuits, Continuously Energized Underway			
GD	Diving alarm system	XNS	Auxiliary stern diving plane angle indicator
K	Shaft revolution indicator system	EG	Engine governor control and tachometer system
1MB and 2MB	Motor order telegraph	PB	Pyrometer indicator.
3MB	Engine control indicator system	TL	Automatic dead reckoning tracer system
N	Rudder angle indicator system	TP	Main ballast indicator system
XNB	Auxiliary bow diving	TR	Hull opening

	plane angle indicator		indicator system
NB	Bow diving plane angle indicator	Y	Underwater log system
NS	Stern diving plane angle indicator	1MC	General announcing system
		7MC	Submarine control announcing system
Class A-3 Circuits, Fire Control			
6PA	Torpedo firing system	17GA1 and GA1	Torpedo data computer
GT	Target designation system	17GA3 and 17GA4	Forward and after gyro angle setting regulators
6R	Torpedo ready light system		
Class A-4 Circuits, Convenience Circuits			
A	Officers' call bells		

B. SWITCH COLOR CODE

Switch	Color
Circuits continuously energized	Yellow
Underway circuits	Black
Battle circuits	Red
Utility circuits	White

C. TYPES OF NAVY SHIPBOARD CABLES

Designation	Description
Lighting, Power, and General Utility Cables	
SHFL	Single conductor, heat and flame resistant, leaded.
DHFA	Double conductor, heat and flame resistant, armored.
SHFA	Single conductor, heat and flame resistant, armored.
DCOP	Double conductor, oil resistant, portable.
SHFS	Single conductor, heat and flame resistant, switchboard cable.
FHFA	Four conductor, heat and flame resistant, armored.

TCOP	Triple conductor, oil resistant, portable.
NOTE: Numbers following the above letters indicate the approximate circular mil area of each conductor with the last three digits omitted.	
Interior Communication and Fire Control Cables	
MHFA	Multiple conductor, heat and flame resistant, armored.
MHFF	Multiple conductor, heat and flame resistant, flexible.
NOTE: Numbers following these letters indicate the number of conductors in the cable. Each conductor has a cross-section area of about 2800 circular mils.	
Telephone Cables	
TTHFA	Twisted pair, telephone, heat and flame resistant, armored.
NOTE: Numbers following letters indicate number of pairs of conductors.	

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D. HOW TO READ A CABLE TAG ON A SUBMARINE

In general, the designating letters for cable tags on light and power circuits are as follows:

FB-light and power battle feeders

XFE-light and power emergency feeders

The numbers used in connection with the designating letters are indicative of voltage. In other words, the voltage may be determined from the name-tag designation.

Example: 115 to 120-volt circuits are numbered from 100 to 199, and 215 to 250-volt circuits are numbered from 200 to 299.

A circuit designation such as FB-216 indicates that it is a 250-volt circuit because the number is in the range from 200-299.

Voltages of less than 100 volts are indicated in the same general way as above, 40 volts being

A lighting feeder is a circuit emanating from the switchboard and supplying one or more mains.

A lighting main is a circuit feeding from a lighting feeder, supplied through a lighting distribution panel, a feeder junction box, or feeder distribution box.

A lighting submain is a circuit feeding from a lighting main supplied through a distribution box.

A lighting branch is a circuit feeding from a submain and supplying fixtures, lights, fans, and other small equipment.

The same general arrangement applies to power distribution. The following are examples of cable markings:

FB-0210: Lighting feeder, supply to lighting switchboard from source of supply.

numbered from 40 to 49, 60 volts from 60 to 69, and so on.

Generator, bus tie, shore connections, main motor, and battery cables use numbers preceded by a zero to distinguish them from the regular feeders, mains, and branches.

Example: A circuit marked FB-0211 would still indicate 250 volts, but it is apparent that it is not a major, or source of supply, cable.

When referring to the marking of lighting and power cables the following terms are used.

A feeder is a cable emanating from a switchboard or from the source of power to the switchboard.

A main is a cable emanating from a feeder.

A submain is a cable emanating from a main.

A branch is a cable emanating from a submain.

A subbranch is a cable emanating from a branch.

When referring to the lighting system only, the following definitions apply:

F8-102: Lighting feeder from lighting switchboard to distribution boxes on port side.

FB-101: Lighting feeder from lighting switchboard to distribution boxes on starboard side.

18-FB-102: Lighting main connected to feeder FB-102 and supplying after engine room.

18-FB-102-IS: Submain in after engine room, starboard.

FB-0218: Power feeder from main generator to control cubicle.

FB-200: Power feeder from after auxiliary power switchboard to panel in crew's mess room.

1-FB-200: Power main from panel in crew's mess room to galley range control panel.

1-F8-200A: Power submain from galley range control panel to range cooking surface.

E. AMERICAN WIRE GAGE (A.W.G.) WORKING TABLE
(U. S. Bureau of Standards)

Gage No. in A.W.G.	Diameter in Mils	Cross Section	Gage No. A.W.G.	Diameter in Mils	Cross Section

		Circular Mils	Square Inches			Circular Mils	Square Inches
0000	460	212000	0.166	19	36	1290	0.00101
000	410	168000	0.132	20	32	1020	0.000802
00	365	133000	0.105	21	28.5	810	0.000636
0	325	106000	0.0829	22	25.3	642	0.000505
1	289	83700	0.0657	23	22.6	509	0.000400
2	258	66400	0.0521	24	20.1	404	0.000317
3	229	52600	0.0413	25	17.9	320	0.000252
4	204	41700	0.0328	26	15.9	254	0.000200
5	182	33100	0.0260	27	14.2	202	0.000158
6	162	26300	0.0206	28	12.6	160	0.000126
7	144	20800	0.0164	29	11.3	127	0.0000995
8	128	16500	0.0130	30	10.0	101.0	0.0000789
9	114	13100	0.0103	31	8.9	79.7	0.0000626
10	102	10400	0.00815	32	8.0	63.2	0.0000496
11	91	8230	0.00647	33	7.1	50.1	0.0000394
12	81	6530	0.00513	34	6.3	39.8	0.0000312
13	72	5180	0.00407	35	5.6	31.5	0.0000248
14	64	4110	0.00323	36	5.0	25.0	0.0000196
15	57	3260	0.00256	37	4.5	19.8	0.0000156
16	51	2580	0.00203	38	4.0	15.7	0.0000123
17	45	2050	0.00161	39	3.5	12.5	0.0000098
18	40	1620	0.00128	40	3.1	9.9	0.0000078

F. DEFINITIONS

Ampere. The rate of flow of electricity. One volt impressed on a circuit having a- resistance of 1 ohm results in a current flow of 1 ampere.

Coulomb. The unit of quantity of electricity. A current of 1 ampere, for example, is a current flowing at the rate of 1 coulomb per second.

Volt. The electrical unit of pressure that causes the electricity to flow.

electrical power. One horsepower equals 746 watts. For rough estimates, to find horsepower, multiply kilowatts by 1 1/3; to find kilowatts, multiply horsepower by 3/4.

Henry. The unit of inductance. The ability of a circuit to produce an emf by electromagnetic induction when the current in the circuit changes.

Farad. The electrical unit of capacitance. A condenser has a capacitance of 1 farad when a

Ohm. The electrical unit of resistance. If a pressure of 1 volt is impressed on a circuit and 1 ampere flows, that circuit has a resistance of 1 ohm.

Watt, kilowatt, horsepower. The units of

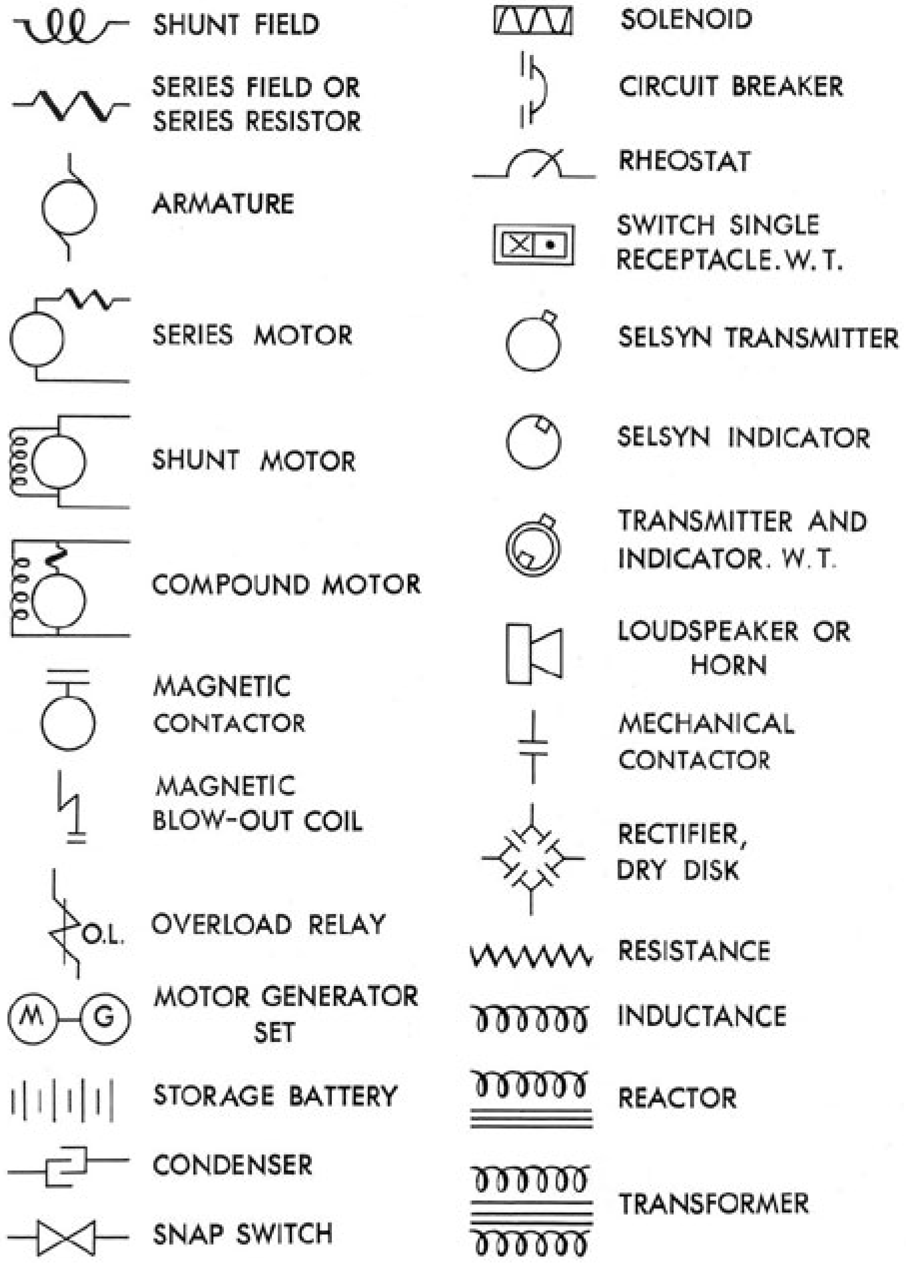
potential difference of 1 volt between the plates of the condenser will store up in it a charge of 1 coulomb. Capacitance is generally expressed in microfarads (one millionth of a farad).

G. CONVERSION FACTORS

To Convert	Multiply By
Inches to centimeters	2.54
Horsepower to watts	746
British thermal units to foot pounds	778
Kilograms to pounds	2.205
Centigrade to Fahrenheit	9/5, then add 32
Fahrenheit to centigrade	5/9, after subtracting 32

H. COMMONLY USED ELECTRICAL SYMBOLS

H. COMMONLY USED ELECTRICAL SYMBOLS



I. SAFETY PRECAUTIONS

1. Research has shown that at least 75 percent of all accidents is the result of carelessness. Hurrying reduces caution and invites accidents. Remembering the following rules will help to prevent accidents:

Always take time to be careful.

Never take chances.

the test lamp; then test the dead side with the same lamp and retest the live side. This is to make certain that the test lamp was in good condition.

6. As a general rule use only one hand for switching. Keep the other hand clear. Only one switch should be touched at a time by one per son. Before closing a switch, make certain that:

Turning one's head to engage in conversation while working may result in an accident. The importance of concentration on the job cannot be overemphasized. The purpose of safety rules should be to create a tendency to think and act in terms of safety. A new man is inclined to expose himself, as well as any equipment on which he may be working, to danger because of inexperience; an experienced man is liable to do the same because of overconfidence and habits of work he may have formed. STOP. LOOK. THINK.

2. Men engaged in the following work must wear eye protectors:

a. Acid working

b. Overhead drilling, reaming, etc.

c. Electric and gas welding, cutting, etc.

d. Grinding .

3. Only authorized persons are permitted to work on electrical equipment.

4. When an electrical circuit is to be overhauled or worked on, the main supply switches or cutout switches in each circuit from which power could possibly be fed should be secured in the open position and tagged. The tag should read, "This circuit was ordered opened for repairs and shall not be closed except by direct order of ...." After the work has been completed, the tag or tags should be removed by the person completing the repairs. In

a. The circuit is ready and all moving parts are free.

b. Men near moving parts are notified that the circuit is to be energized.

c. Proper fuses are installed for protection.

d. The circuit is closed.

Ease the switch to a position for safe quick action and then make the final motion positive and rapid. In opening switches carrying current, the break should be positive and rapid. An exception to this rule is the case of the supply switches to the main generator and main motor field. These are opened slowly to permit the arc to dissipate the stored inductive energy of the coil in order to protect the insulation of the coil.

7. Fuses are safety devices and should be used as such. Fuse pullers made of insulating material should be used for their removal or replacement. Fuses larger than 10-ampere rated capacity should be removed and replaced only after the circuit has been completely deenergized. When a fuse blows, it should be replaced with a fuse of the same rated ampere capacity. Never short out a fuse.

8. Except for operating handles, all parts of circuit breakers normally are conductors. In opening and closing circuit breakers, observe the following precautions:

a. Use only one hand.

b. Keep the hands clear of parts other than the operating handles.

the event that more than one working party is engaged in repair work on an electrical circuit, a tag for each party should be placed on the supply switches.

5. All electrical leads should be considered as live until it is positively proved that they are not. To check a circuit, test the live side with

c. Touch only one breaker handle at a time.

d. Where positive and negative breakers have two handles, they should not be closed at one time.

e. Close the breaker first and then close the switches.

f. Trip the circuit breakers before opening the switches.

g. Never disable a circuit breaker.

h. Keep the face turned away while closing circuit breakers.

i. Never stand over a circuit breaker.

9. In so far as is practicable, repair work on energized circuits should not be undertaken. When repair work considered by the commanding officer as essential is undertaken on an energized circuit, it should be accomplished by an electrician's mate under the supervision of an electrician or an experienced engineer officer. In all such work every care should be taken to insulate the person performing the work from ground and to use every known safety precaution. The following precautions must be observed:

a. Provide ample illumination.

b. Remove loose clothing.

10. Cleaning of energized switchboards, panels, boxes and the like should be limited to removing loose dirt with a painter's duster having no metallic parts and made of soft bristles about 4 inches long.

11. Alcohol should not be used on energized equipment or on equipment that is close to a source of sparks. Alcohol should be exposed in the smallest possible quantity, and should be used only in well-ventilated compartments. Wherever possible, no more than a pint of alcohol should be taken to any one job.

12. Volatile liquids such as insulating varnish, paint, lacquer, turpentine, or kerosene produce inflammable vapors. In working with these liquids ample ventilation should be provided to prevent the accumulation of fumes.

One of the most common and useful cleaning solvents is carbon tetrachloride. This substance must never be used in a confined space and should not be taken to sea in a submarine, as the fumes are toxic and submarine crews have

c. Insulate worker from ground with dry wood, several layers of dry canvas, or a sheet of phenolic material or sandpaper.

d. Cover working metal tools with insulating rubber tape, not friction tape, as far as is practicable.

e. Insulate live metal parts near the place where work is to be done.

f. If practicable, use only one hand in accomplishing the work.

g. A rubber glove should be used on the hand not used for handling tools. If the work permits, rubber gloves should be worn on both hands.

h. Have men stationed by circuit breakers or switches, and telephones manned if necessary, so that the circuit or switchboard can be deenergized immediately in case of emergency.

i. A man qualified in first aid for electric shock should stand by during the entire period of repair.

been poisoned by them through leakage of the containers.

13. The risk of accidental contact with live circuits always exists. As a general rule, persons working around live circuits should not approach closer than 1 foot regardless of voltage except to accomplish a particular mission. While accomplishing this mission - STOP, LOOK, THINK.

14. In case of an electrical fire, proceed as follows

a. Deenergize the circuit.

b. Report the casualty to the officer of the deck by messenger or telephone.

c. Secure ventilation.

d. Extinguish the fire.

In extinguishing an electrical fire it should be remembered that quick action is required only in deenergizing the circuit. A CO_2 fire extinguisher directed at the base of the flame is always best for electrical fires. Pyrene or carbon tetrachloride is effective in extinguishing an electrical fire that is wholly in the open. But when used in a closed space, it forms a gas, as a result of heat, that causes loss of consciousness. Pyrene

or carbon tetrachloride therefore should never be used in a confined space for fire fighting. Fresh water used intelligently is good for extinguishing a fire. The use of salt water is dangerous. Foam-type fire extinguishers should never be used in fighting

18. No person should take loose metal parts or liquids near or above a switchboard or other open electrical apparatus. No person should go above open electrical apparatus without first removing all metal from his pockets. Stowage or insertion of

electrical fires. In case of cable fires in which the inner layers of insulation, or insulation covered by armor, support combustion, the only positive method of preventing the fire from burning the length of the cable is to cut the cable and separate the ends.

15. Intentionally taking a shock from any voltage is dangerous and is strictly forbidden. Whenever it becomes necessary to check a circuit to see if it is alive, a test lamp, voltmeter, or other suitable indicating device should be used.

16. In the case of live circuits, never implicitly trust insulating material. Insulating material has been known to fail on more than one occasion.

17. If open-type electrical apparatus is in operation when the presence of explosive vapor is detected, the apparatus should be deenergized by means of remotely located switches. The switches should be opened only after it has been ascertained that all persons are clear of the dangerous space.

foreign articles in or near switchboards, control appliances, panels, and so forth is forbidden.

19. Covers for all fuse boxes, junction boxes, lever type boxes, and wiring accessories, in general, should habitually be kept closed.

20. In general, cables that are installed where they will be subject to mechanical injury should be protected within such exposed zones by suitable metal casings.

21. Portable cables should be carefully selected and should be of the proper length and cross-sectional area. Spliced portable cables are extremely dangerous and should not be used.

22. The static electrical charge retained by electrical machinery when secured is in certain cases sufficient to cause a severe shock. This should be considered when making connections to an apparently dead machine. Be safe-discharge it to the ground.

J. FIRST AID

1. Treatment for electric shock. A person who has been accidentally shocked by electricity and whose breathing has stopped is not necessarily dead. He may be only stunned or his breathing may have stopped only momentarily. The following instructions should be followed

a. Break the circuit immediately.

e. If it is necessary to cut a live wire, use an ax or hatchet with a dry wooden handle, or insulated pliers.

f. If the victim is suffering from burns, use the treatment for burns described in this section.

g. Apply warmth to the victim's body, rub his skin and muscles, and administer stimulants if he can swallow.

b. Separate the victim from the live conductor by a quick motion, using a nonconductor, such as dry rope, a dry coat, or a dry board. The victim's clothes, if dry, may be used to pull him from the live wire. Do not use anything wet or metallic.

c. Beware of touching the heels or soles of the victim's shoes.

d. Do not touch his body with your hands unless they are covered with rubber gloves, dry clothing, or other nonconducting material.

2. Resuscitation. As soon as the victim is clear of the conductor, begin administering artificial respiration. The patient's mouth should be cleared of any obstructions such as chewing gum or tobacco, false teeth, or mucus, so that there is no interference with the entrance and escape of air. The patient must be kept warm during artificial respiration and it may be necessary to cover him with blankets and work through them, as well as to apply heat by means

of hot water bottles, hot bricks, and so forth. Be careful not to burn the patient.

There are several accepted methods of applying artificial respiration, but the best and probably the least dangerous is the prone pressure, or Schaefer, method which follows.

3. Artificial respiration, Schaefer method. a. Position. 1) Place the patient on his stomach, one arm extended directly overhead, the other arm bent at the elbow and with the face turned outward and resting on hand or forearm, so that the nose and mouth are free for breathing.

2) Kneel, straddling the patient's thighs.

3) Place the palms of your hands on the small of the victim's back with your fingers resting on his ribs, the little finger just touching his lowest rib, the thumb and

When the patient revives, he should be kept lying down to avoid strain on the heart. Give him a stimulant, such as a teaspoonful of aromatic spirits of ammonia in a small glass of water or a hot drink of coffee or tea. Continue to keep the patient warm and at rest.

As a general rule the victim should not be moved until he is breathing normally and then moved only in a lying position. Should it be necessary to move the patient before he is breathing normally, resuscitation should be carried on during the time that he is being moved.

A brief return of natural respiration is not a certain indication for stopping the resuscitation. Not infrequently, the patient, after a temporary recovery, stops breathing again. He must be watched closely, and if natural breathing stops, artificial respiration should be resumed at once.

fingers in a natural position, and the tips of the fingers just out of sight.

b. First and second movements. 1) With your arms held straight, swing forward slowly, so that the weight of your body is gradually brought to bear upon the patient. The shoulder should be directly over the heel of the hand at the end of the forward swing. Do not bend your elbows. This operation should take about 2 seconds.

2) Now immediately swing backward, so as to remove the pressure completely.

3) After 2 seconds, swing forward again. Repeat, 12 to 15 times a minute, the double movement of compression and release; a complete cycle of respiration in 4 or 5 seconds.

Continue artificial respiration without interruption until natural breathing is restored. Do not become discouraged if your efforts seem to be in vain. Resuscitation often has to be continued a long time before signs of life are apparent. Do not discontinue your efforts until you are absolutely certain that the patient is dead. Sometimes, even after several hours work, resuscitation occurs.

Do not feed the patient any liquids until he is fully conscious.

In carrying on artificial respiration, it may be necessary to change the operator. This change must be made without losing the rhythm of respiration. The relief operator should kneel behind the man giving the artificial respiration, and at the end of the movement, the operator crawls forward while the relief takes his place. By this procedure no confusion results at the time of change of operator, and the established rhythm is maintained.

4. Treatment of burns. Burns result from exposure of the body to dry heat or to strong acids and alkalis, while scalds follow exposure to moist heat, such as hot water or steam. These are serious accidents, attended, at times, with marked shock, and their danger to life depends more upon the extent of the body surface involved, than the degree. The passage of strong electric currents through the body also causes burns.

For convenience, burns are classified as follows:

First degree burns: Reddening of the skin.

Second degree burns: Reddening of the skin with formation of blisters.

Third degree burns: Charring and destruction of the deeper tissues.

There is usually considerable pain with burns and, if the burned area is extensive, marked shock.

its own accord, when the loosened parts may be cut away with sterile scissors.

Air must be excluded from the burned part. This may be done by means of tannic acid jelly dressings, or by a paste made with water and baking soda, starch, or flour. If the burn was caused by a caustic such as an acid or an alkali, the acid should be neutralized with bicarbonate of soda (ordinary baking soda). If the burn was caused by an alkali, neutralize with a weak solution of acetic acid (ordinary vinegar) before the burned area is covered. Whenever possible, burns should first be treated with tannic acid jelly. If a person is extensively burned, the quickest temporary means of excluding air is to immerse the burned area or the entire body in lukewarm water. Then, having everything in readiness, carefully cut away the clothing, leaving any that may be sticking to the burned skin. The application of tannic acid jelly dressings should follow and the patient put to bed. In case the supply of tannic acid jelly is inadequate, a satisfactory tannic acid solution can be made by pouring one quart of boiling water over 2 1/2 ounces of tea leaves. Allow to steep for at least 15 minutes, then strain. This solution can be applied to the burned area by means of an atomizer or sterile cotton applicators. Several coats of the tannic acid solution are applied while an assistant fans the areas to promote the tanning process. The tannic acid unites with and tans the tissues in the raw areas. When tanning is complete, the burned areas are dark brown in color, and when they have dried they are covered with a hard, leathery crust of a dark brown or The effectiveness of this method of treating burns is seriously interfered with if oils, ointments, or other greasy substances have previously been applied to the burned areas. Any oil, ointment, or grease that is present must be gently but thoroughly removed with a sterile swab and the area sponged with a weak solution of sodium bicarbonate before the tannic acid treatment is begun, even though it may cause considerable suffering.

If tannic acid is not available, an excellent dressing is a solution of ordinary baking soda (2 tablespoonfuls in a pint of boiled water). A salt-solution dressing is also good (a teaspoonful of a common salt in a pint of boiled water). Do not use strong antiseptics on burns. Soaking the injured part in lukewarm water is good and is very often useful to soak off clothing sticking to a burned surface. If blisters have formed and are painful, they may be opened by passing a sterile needle through them and allowing the fluid to escape. Do not destroy the skin raised by a blister. The needle used may be sterilized by burning in a flame. Do not put cotton next to a burn; it sticks and causes trouble. In dressing burns take a pad of sterile gauze, soak in the solution, apply to the affected areas, and hold in place by bandage. In removing the dressings, it is often necessary to soak them off, and warm water or one of the solutions mentioned above may be used for this purpose.

The patient should be allowed to rest and if there is much pain, phenobarbital and aspirin tablets

black color. Unless infection occurs beneath it, the crust should not be disturbed until it begins to curl up at the edges and to peel off of may be given. There may be considerable shock accompanying the burn. A person badly burned should be attended by a physician as soon as possible.

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