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ELECTRONIC INSTALLATION PRACTICES MANUAL

CHAPTER 15

MOTORS, GENERATORS AND AMPLIDYNES

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LIST OF EFFECTIVE PAGES

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ELECTRONIC INSTALLATION PRACTICES MANUAL

This manual is intended for the use of the electronic installation worker. It may be used as a reference book on installation practices or in training beginners in Naval electronic installation work.

Subject matter in this text is intended as supplementary to, but not superseding existing and applicable specifications.

Appreciation is extended to the various Naval Shipyards, Commercial Firms, Service Representatives and Manufacturers who were consulted and without whose cooperation this manual would not be possible.

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SECTION 15-1

GENERAL DESCRIPTION

1. INTRODUCTION.

The primary purpose of this chapter is to provide electronic installation personnel with information and procedures necessary for the proper installation and care of motors, generators, and amplidynes.

Motors, generators, and amplidynes are used wherever power and mechanical drive applications are required for operation of electrical or electronic equipments on board ships. These applications include antenna-train mechanism, gun-control circuits, motor-generator sets and others.

Motors convert electrical energy to mechanical energy. Generators convert mechanical energy to electrical energy. Amplidynes are units capable of controlling large amounts of power proportionally to small control signals.

Since the majority of motor and generator applications in electronic work involve motor-generator sets and amplidynes, this section will discuss motor and generator types and characteristics generally so as to provide the proper background for discussing motor-generator sets and amplidynes in later sections.

In the following sections, both AC and DC machinery will be discussed. Sixty cycles per second is now almost invariably the standard frequency for general alternating-current service. Single-phase supply is used for lighting systems and small motor loads. Of the polyphase systems the two phase is now seldom used, as the three phase is somewhat more economical.

2. GENERATORS.

The essential parts of any motor or generator are the armature and the field. The field may be stationary and the armature rotated, or the armature may be stationary and the field rotated. In either case, the rotating member is called the rotor and the stationary member is called the stator.

Two types of generators are described in the following paragraphs. These are the direct-current generator and the alternating-current generator.

a. DIRECT-CURRENT GENERATORS. – In the direct-current generator the armature is usually the rotating part. It carries the conductors which cut the magnetic field set up by the field poles. The field consists of two, four, six, or any other multiple of two-pole pieces wound with electro-magnetic windings.

To deliver the generated voltage included in the armature to the load circuit, a commutator-brush system is used. See Figure 15-1. The commutator is peculiar to DC generators. It causes a continual changing of the relative connection of the conductors inside the armature and the external circuit,

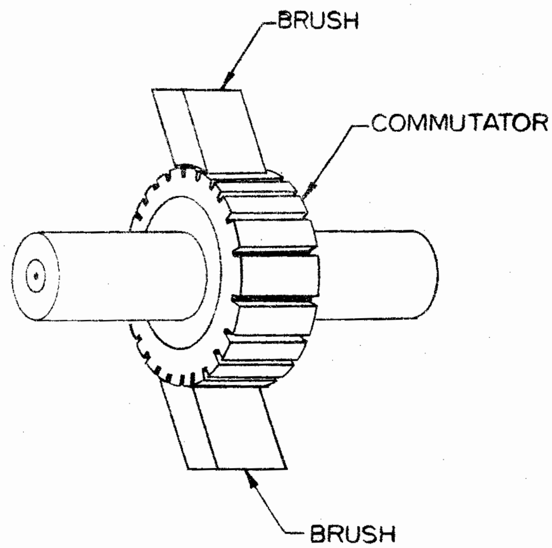


Figure 15-1. Commutator-Brush System

so that regardless of the fact that the voltage of each internal conductor is continually changing in value and direction, the external circuit receives a voltage of practically constant value and constant direction of polarity.

The commutator consists of a large number of copper bars of a segmental cross section, each insulated from its neighbor by mica and formed into a hollow cylinder. The brushes are small slabs of carbon pressing and rubbing against the outer surface of the commutator. Their function is to make a continuous electrical connection between the moving conductors of the armature and the stationary conductors of the external circuit and to carry the current out from and back to the armature.

Direct-current generators are divided into five types according to the method in which they are connected. Four of these types are shown schematically. It should be noted that DC motor types have identical schematics. They are as follows:

(1) SHUNT CONNECTION. – The armature and field are in parallel.

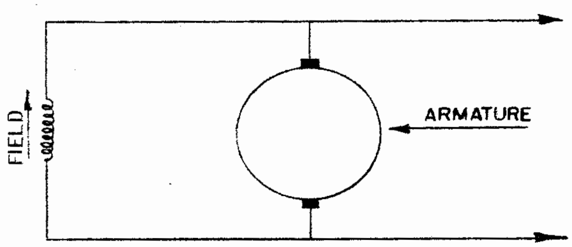


Figure 15-2. Shunt Connection

(2) SERIES CONNECTION. – The armature and field are in series.

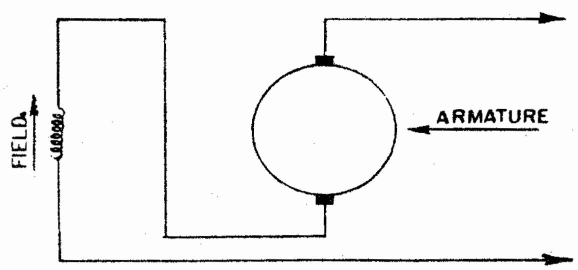


Figure 15-3. Series Connection

(3) CUMULATIVE-COMPOUND CONNECTION. – The armature is connected to two field windings, one in series and one in parallel. The windings carry current in the same direction and thus help to produce a stronger flux field.

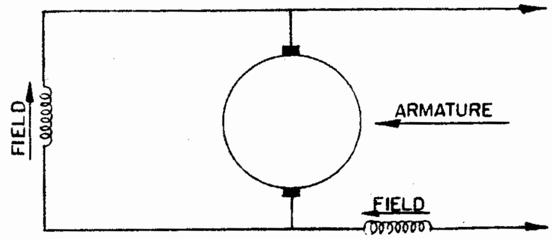


Figure 15-4. Cumulative-Compound Connection

(4) DIFFERENTIAL-COMPOUND CONNECTION. – The armature is connected to two field windings, one in series and one in parallel. The windings carry current in opposite directions. They oppose each other and produce a weaker field.

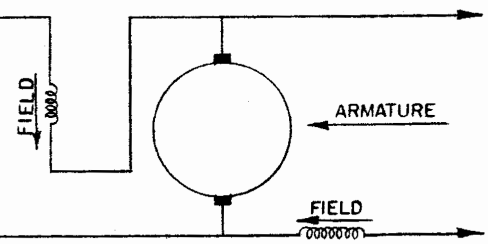


Figure 15-5. Differential-Compound Connection

(5) SEPARATELY-EXCITED CONNECTIONS. – The armature has no connection with its own field.

b. ALTERNATING-CURRENT GENERATORS (ALTERNATORS). – In a DC generator, a commutator is used to change the generator voltage to a DC voltage. If slip rings, Figure 15-6, are used instead of a commutator, alter-

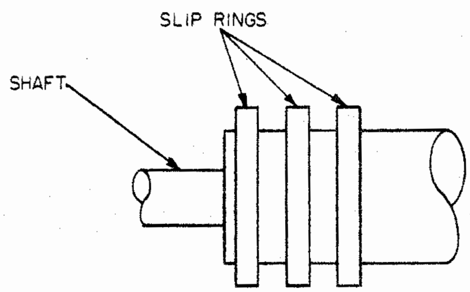


Figure 15-6. Slip Ring Assembly

nating current will be supplied to the load. The fundamental principle for the generation of a voltage in an AC generator is the same as in a DC generator. That is, the generation of a voltage in the armature conductor, depends only on a relative motion between the conductor and the flux field.

In practically all AC generators the armature is stationary and the field is rotated. This construction has certain advantages. A rotating armature requires slip rings for carrying current to the external load. Such rings are difficult to insulate and are a frequent source of trouble, often causing opens and short circuits. A stationary armature requires no slip rings. The armature leads can be continuously insulated conductors from the armature coils to the bus bars. Also, it is more difficult to insulate the conductors in a rotating armature than in a stationary one, because of the centrifugal force resulting from rotation. The stationary armature makes it possible to operate alternators at voltages that are impossible in DC generators. The armature is made up of a laminated iron core and windings. The windings are embedded in slots in the core and the core is secured to the stator frame. The field of the alternator is placed upon the rotor. The AC generator is separately excited by a DC generator. The DC generator may be driven by the same shaft that drives the rotor of the AC generator or by a separate mover.

3. MOTORS.

Before attempting the selection of a type of motor, it is necessary to know what will be required of it as to frequency of starting, magnitude of starting torque, running speed, necessity for speed variation, variability of load, overload capacity, temperature and humidity of surrounding atmosphere, presence of dust or explosive gasses, motor mounting, and any special limitations that may be imposed by supply circuit requirements such as low starting current and high power factor.

If the supply is direct current, the selection of motors is greatly simplified because the available types of motors are reduced to three and each of these has very desirable characteristics for certain kinds of work. For starting moderate loads infrequently and operating them at constant speed, the shunt motor is most desirable. For operating at speeds adjustable over a wide range, each setting to be unaffected by load, this same motor is used with field resistance control.

The series motor is especially suited for starting heavy loads frequently and operating at any speed that may suit the load.

For operating heavy loads more or less frequently, but with less variation of speed with load, the compound motor serves best; if greater torque is required only at starting, the series field of the compound motor may be cut out after starting.

Because of the steadily increasing use of alternating-current circuits, motor selection is now becoming more restricted to alternating-current types. For constant-speed service and infrequent starting at ordinary loads, the induction motor with a low-resistance, squirrel-cage winding gives very good results, especially where a rugged and simple machine requiring little attention is desired. If the starting torque does not have to be as high and if a high power factor is of importance, a synchronous motor should be considered. It can give a leading power factor, if desired, to overcome the lagging factor of induction motors and it will run very efficiently at constant speed, but it needs direct current for excitation.

Where a higher starting torque is needed without excessive starting current, an induction motor with a high resistance rotor may be used; however, the efficiency of this type induction motor is somewhat lower than that of the low-resistance, squirrel-cage motor.

The wound-rotor or slip-ring type of induction motor meets the requirements of high torque with minimum starting current. External resistance is provided for the rotor circuit. This resistance is gradually cut out during starting and it may be cut in while the machine is running to secure a gradual reduction of speed to about one half of normal speed. This is the only type of polyphase alternating-current motor used extensively for speed adjustment.

For power service on single-phase circuits, the repulsion-start induction motor is widely used since it combines good starting and running characteristics.

In determining motor ratings, it is always well to choose sizes which will be loaded well up to their rated capacities. Formerly it was customary to select oversize motors, but this means that they may operate most of the time at only a small part of their rated load. This results in low efficiency and with induction motors, also in low power factor.

The following paragraphs describe motors classified as to winding type in more detail. In addition, such factors as the degree of exclosure, standard voltages, speed and power and methods of cooling are also discussed. Data on small, fractional-horsepower motors is summed up in Table 15-1.

a. TYPES OF WINDINGS.

(1) DC MOTORS.

(a) SHUNT MOTOR.—The main field windings and the armature are connected in parallel. (Figure 15-2.) The field takes only a small portion of the line current. A shunt motor will run at very nearly the same speed at any load within its capacity. For this reason these motors are generally classed among constant-speed motors. Their speed can be changed however, since the voltage across the armature and the strength of the field determine the speed of a direct-current motor. If the voltage to the armature is cut in half, the speed will be cut in half; if the voltage is doubled, the speed will be doubled, provided the field strength doesn't change.

If the magnetic field is weakened, the motor will speed up; if the field is strengthened, the motor will slow down.

(b) SERIES MOTOR. – A series-wound motor is one in which the field coils and armature are connected in series and the entire line current flows through the field coils. (Figure 15-3.) The speed varies greatly as the load changes. With each increase in load it will slow down, but it is capable of carrying a very heavy overload before being stalled. It has better starting characteristics than the shunt motor and is used for service requiring frequent starting and good starting torque.

(c) COMPOUND MOTOR. – A compound-wound motor has both series and shunt-field windings (Figures 15-4 and -5) and, because of this, they combine the characteristics of series and shunt machines. The speed changes as the load changes but it doesn't change as much as in a series motor and it usually changes a great deal more than a shunt motor. The shunt winding fixes a maximum speed, beyond which the motor will not run even at no load, and the series winding causes it to drop in speed as the load increases. Like the series motor, it has excellent starting characteristics for heavy loads and yet is in no danger of "running away" at light loads when used without a speed controller.

(2) AC MOTORS.

(a) SPLIT-PHASE, CAPACITOR MOTOR. – This motor is a single-phase induction motor with a main winding arranged for direct connection to a source of power and an auxiliary winding con-

TABLE 15-1. SMALL MOTOR DATA

Type Motor			HP Range	Speed Data			Starting Torque	Built-in Starting Mechanism	Reversibility		Radio Interference
				Rated Speed	Charac-teristics	Speed Control			At Rest	In Motion	
Alternating Current	Single Phase	Split phase general purpose	1/20 to 1/3	3450 1725 1140 860	constant	none	medium	centrifugal switch	yes	no	none
		Capacitor-start induction-run	1/8 to 3/4	3450 1725 1140 860	constant	none	extra high	centrifugal switch	yess	no	none
		Capacitor run	1/20 to 3/4	1620 1080 820	constant or adjustable varying	2 speed switch or autotrans-former	low	none	yes	no	none
		Shaded pole	1/300 to 1/30	1500 1000	constant or adjustable varying	choke coil	low	none	no	no	none
	Polyphase	Squirrel Cage induction	1/6 to 3/4		constant	none	high	none	yes	yes	none

TABLE 15-1. SMALL MOTOR DATA (Cont'd)

Type Motor		HP Range	Speed Data: Rated Speed	Speed Data: Characteristics	Speed Data: Speed Control	Starting Torque	Built-in Starting Mechanism	Reversibility: At Rest	Reversibility: In Motion	Radio Interference
Direct Current	**Shunt wound and** compound wound	1/20 to 3/4	3450 1725 1140 860	constant or adjustable varying	armature resistance	extra high	none	yes	no	yes
Direct Current	Series wound	1/125 to 1/30	2000 to 900	varying or adjustable varying	resistance	extra high	none	yes	no	yes
Universal AC or DC	Universal compensated or noncompensated	1/150 to 2-1/2	1500 to 15000	varying	voltage control using resistance or transformer	extra high	none	no	no	yes
Universal AC or DC	Universal governor controlled	1/50 to 1/20	2000 to 6000	adjustable constant	adjustable governor	extra high	none	no	no	yes

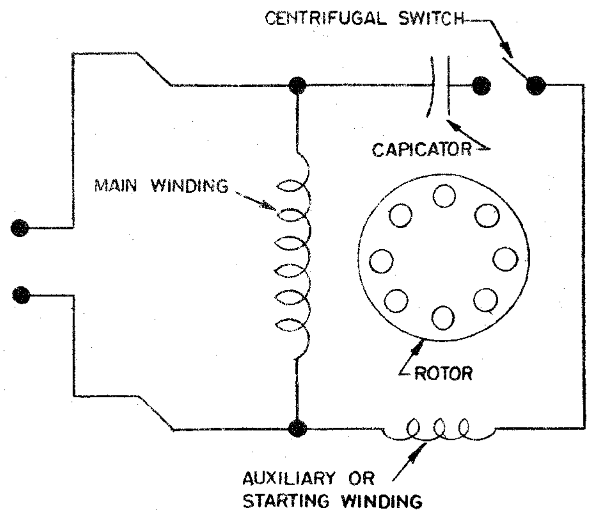


Figure 15-7. Capacitor-Start Motor Circuit Diagram

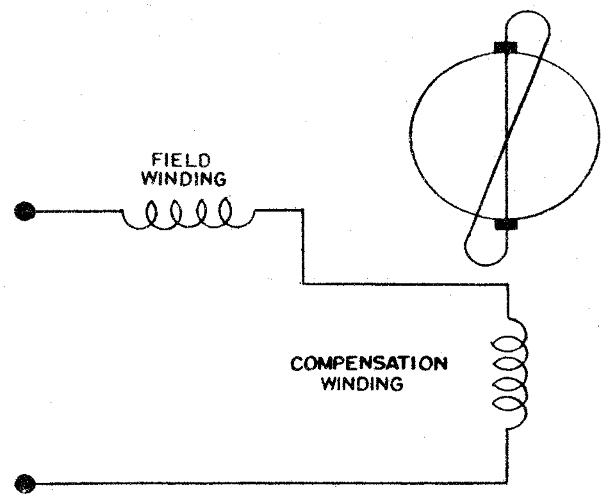


Figure 15-8. Repulsion Motor Circuit Diagram

nected in series with a capacitor. In the capacitor-start, induction-run motor, a centrifugal switch opens the auxiliary winding when the motor reaches operating speed. In the capacitor-start, capacitor-run motor, the capacitor and auxiliary winding are left in the circuit at all times. This is an all-purpose motor for high starting torque, low starting current, quietness and economy. Power factor and efficiency are very good. (Figure 15-7.)

(b) REPULSION MOTOR. - This motor has a stator like that of most single-phase motors and a rotor like the armature of a direct-current motor, but the brushes on the commutator are short-circuited. The brushes are placed so that the magnetic axis of the rotor winding makes a small angle with the neutral axis of the magnetic field of the stator. (Figure 15-8.)

The repulsion motor has characteristics similar to the series motor; that is, varying speed with load, high starting torque and moderate starting current. However, it has low power factor except at high speeds. For this reason, it is often modified into the "compensated" repulsion motor or the "repulsion-induction motor", or the "repulsion-start" induction motor. In these constructions, it serves as a combination of the repulsion and single-phase induction motors. Still another modification, known as the "series-repulsion motor", combines the characteristics of the series motor and simple repulsion type.

(c) UNIVERSAL MOTOR. - A universal motor is a series (Figure 15-9) or compensated-series motor that may be operated at approximately the same speed and output on either direct current or single-phase alternating current of approximately the same voltage. They are generally confined to fractional horsepower sizes. Fundamentally, it is a high speed and varying speed motor with high starting torque.

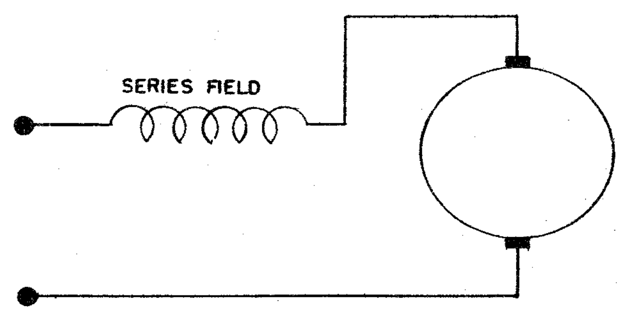


Figure 15-9. Universal Motor Simple Series Diagram

The compensating windings usually appear only on the larger series motors. There are two types of compensating windings. When connected as shown below, it is conductively compensated.

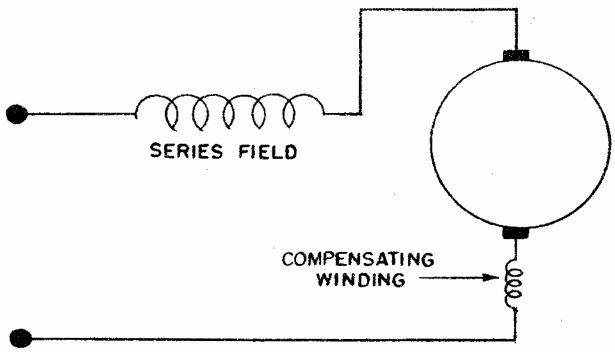


Figure 15-10. Universal Motor
Conductively Compensated

The other type shown below is known as inductively compensated. When connected in this manner, however, the motor can be used on AC only.

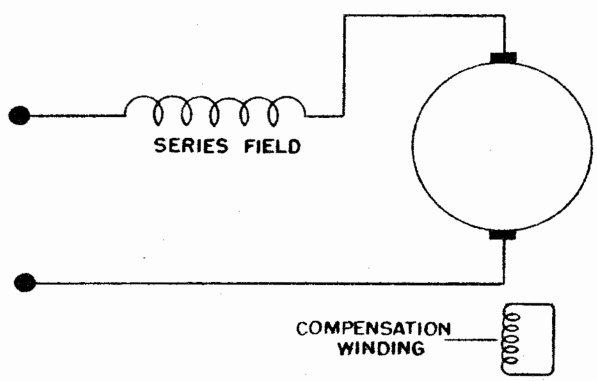


Figure 15-11. Inductively Compensated Series Motor

(d) SHADED - POLE MOTOR.- The shaded-pole motor is a single-phase induction motor equipped with a permanently short-circuited winding of relatively high resistance in the stator at an electrical angle of 30 to 60 degrees from the main winding to provide starting torque. They are used only in very small sizes where simplicity, low torque

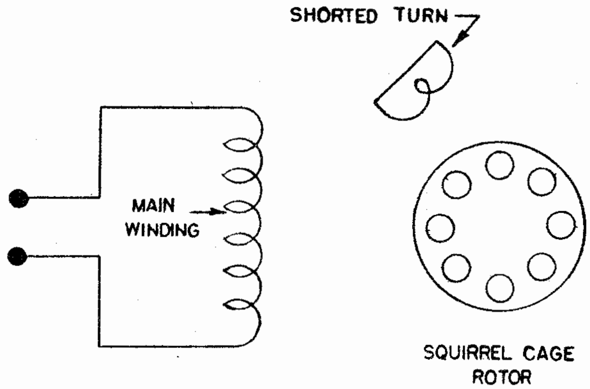


Figure 15-12. Shaded-Pole Motor
Circuit Diagram

and low cost are suited to the requirements.

(e) SQUIRREL-CAGE INDUCTION MOTOR. - An induction motor is one in which the magnetic field in the rotor is induced by currents flowing in the stator. The rotor has no connections to the line. The most common form of induction motor is the "squirrel-cage" motor, so named because the rotor winding resembles the wheel of a squirrel cage. The rotor winding is made up of longitudinal bars in slots just below the outer surface of the rotor. The bars terminate at and are short-circuited by rings at the ends of the rotor. (Figure 15-13.)

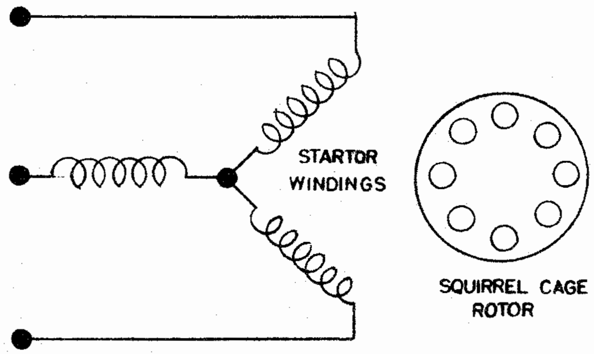


Figure 15-13. Squirrel-Cage Induction
Circuit Diagram (Three Phase)

These motors have general application where three-phase power is available. They are considered to be constant-speed motors. Changes in the rotor resistance affect the characteristics of the motor. For example, an increase in rotor resistance gives an increase in starting torque with a decrease in speed and efficiency. These motors can be built for high efficiency alone, or high starting torque, or high power factor, but there is a limit which prohibits these motors from excelling in all these characteristics. Most induction motors have a well-balanced design so as to give the best starting torque consistent with high power factor and efficiency.

(f) WOUND-ROTOR INDUCTION MOTOR.- This motor is similar to the squirrel-cage motor except that the rotor winding is made up of insulated coils. The terminals of the coils are brought out to slip rings. Leads from the brushes on the slip rings are brought out to an external resistance which can be regulated. By inserting external resistance in the rotor circuit when starting, high torque can be developed with low values of starting current. As the motor speeds up, the resistance is cut out until at full speed the rotor windings are short-circuited. These motors are used where large starting torque and low starting current is required or where speed control is desired (Figure 15-14).

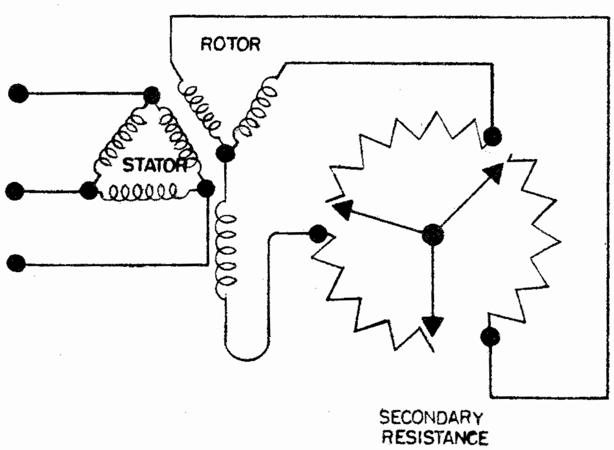


Figure 15-14. Wound Rotor Circuit Diagram

(g) SYNCHRONOUS MOTOR. - A synchronous motor is one which rotates at the same speed as the alternator that supplies its power, or at a fixed multiple of that speed. This speed is fixed by the frequency of the supply circuit and the number of poles of the motor and is dependent of the load up to the "pull-out" point. In construction it doesn't differ much from an alternator. DC excitation is necessary for the field coils (Figure 15-15).

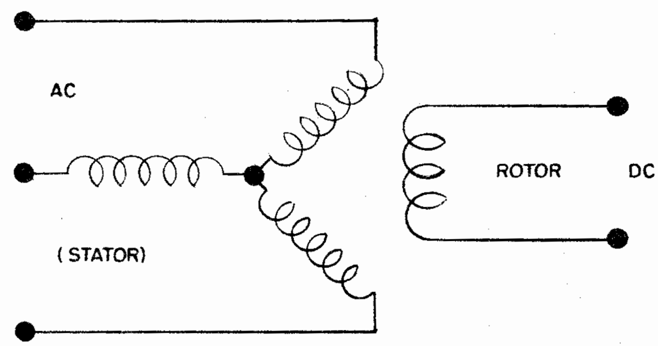


Figure 15-15. Synchronous Motor

Speed is absolutely constant. Power factor control of the motor is accomplished by varying the field current and in this manner power factor correction of the supply source is possible.

The efficiency of synchronous motors is much higher than corresponding induction motors of the same rating. Starting torque is the same since synchronous motors are started as induction motors.

(h) TWO-PHASE INDUCTION MOTOR. - The two-phase induction motor is widely used in low-power servos. The stator has two similar windings arranged to magnetize the machine in perpendicular directions. The rotor may carry either a short-circuited winding or a squirrel-cage winding. The stator coils are usually supplied with AC equal in magnitude, but 90° apart in phase. This may be obtained directly from a two-phase system or from a single-phase source by means of a phase shifter.

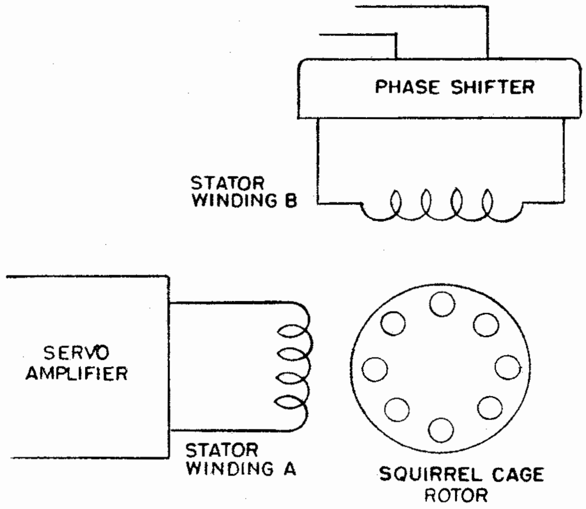


Figure 15-16. Two-Phase Induction Motor

The direction of rotation of the motor may be reversed by interchanging the connections of either stator coil. (Figure 15-16.)

b. DEGREE OF ENCLOSURE.–Motors are classified according to their degree of enclosure as follows:

(1) OPEN. – Motor is self-ventilated, having no restrictions to ventilation other than that necessitated by mechanical construction.

(2) DRIP-PROOF. – Motor is protected against moisture or dirt from any direction up to 45 degrees from the vertical.

(3) PROTECTED. – A motor of this type has all ventilation openings protected with wire screen or perforated covers.

(4) ENCLOSED. – A motor which is entirely enclosed except for openings provided for admission and discharge of air.

(5) SPRAYTIGHT. This type of motor is so constructed that a stream of water from a hose may be played on it from any direction without leakage to the motor.

(6) SUBMERSIBLE. – A motor that will operate under water.

c. SPEED. Motors are classified according to speed as follows:

(1) CONSTANT-SPEED.– A constant-speed motor is one in which the speed remains practically constant from no-load to full-load without requiring currents of the machine.

(2) VARYING-SPEED. – A varying-speed motor is one in which the speed varies with the load, usually decreasing as the load increases.

(3) ADJUSTABLE-SPEED.– An adjustable-speed motor is one in which the speed can be varied gradually over a considerable range, but when once adjusted, remains practically unaffected by the load.

d. VOLTAGE.

(1) DC MOTORS. – Most DC motors used on shipboard are designed for 115 volts or 230 volts.

(2) AC MOTORS.

(a) SINGLE-PHASE

115 volts
230 volts

(b) THREE-PHASE

110 volts
220 volts
440 volts

NOTE

Unless otherwise specified, the standard frequency for AC motors is 60 cycles per second.

e. POWER. - The following are the standard horsepower sizes of motors.

(1) STANDARD HORSEPOWER SIZES.

(a) FRACTIONAL

1/20	1/6	1/3	3/4
1/12	1/5	1/2	7/8
1/8	1/4	5/8	

(b) GREATER THAN ONE

1	3	10	25
1-1/4	4	12-1/2	27-1/2
1-1/2	5	15	30
1-3/4	6	17-1/2	35
2	7-1/2	20	40
2-1/2	9	22-1/2	45
(over 50 - as required)			50

f. METHOD OF COOLING.

(1) NATURAL VENTILATION. - A motor which is cooled by the natural circulation of air caused by the motors own rotation.

(2) SELF-VENTILATED. - This type is cooled by a fan attached to the rotor of the motor.

(3) SEPARATELY-VENTILATED.- A motor which is cooled by an independent fan or blower apart from the motor.

g. DUTY.- All motors on board Naval vessels are classified according to the duty they are to perform. There are two classifications as follows:

(1) CONTINUOUS - DUTY. - A motor capable of being operated at its rated output without exceeding specified temperature limits.

(2) INTERMITTENT-DUTY.- A motor capable of being operated at its rated output for a limited period without exceeding its specified temperature limit.

4. MOTOR-GENERATOR SETS.

The purpose of a motor-generator set is to change an available type of power to a desired type of power. The change may be from DC to AC, AC to DC, from one frequency to another, one voltage to another, or combinations of these.

Each motor-generator set consists of a driving motor and one or sometimes two generators. A coupling is provided to connect the motor and the generator mechanically together. Most motor-generator sets have stationary components of all machines rigidly coupled together as on a mounting bed so that the combined unit will be capable of maintaining proper alignment without depending on the supporting structure of the ship. The motors and generators previously discussed are the types used in various combinations to make up the motor-generator sets commonly found in electronic installations. In electronic applications, the motor-generator sets, when used, are usually designed to supply power for one particular equipment, each equipment having its own motor-generator set. A typical motor-generator set is shown in Figure 15-17.

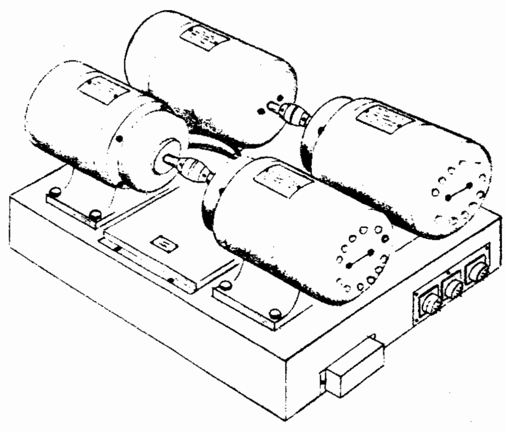


Figure 15-17. Typical Motor-Generator Set

As it is turned by the operator, a very small signal is generated, the strength and polarity of which is determined by the speed and direction the handwheel is turned. This signal is fed into the control field of the amplidyne which amplifies it into sufficiently large power to run the large hydrophone motor. The hydrophone, which is geared to the motor, follows exactly and instantly the motion of the handwheel.

6. RADIO INTERFERENCE.

a. SOURCES.– One of the most severe sources of radio interference aboard ship is that resulting from the operation of rotating electrical machinery (motors, generators) supplied with commutators or slip rings. The sparking resulting from commutation present in nearly all direct - current motors and generators is a cause of radio interference, the amount of interference depending upon the type of commutation used, the power handled during commutation, and other mechanical and electrical characteristics of the rotating equipment. Alternating - current generators, in general, are not as troublesome as direct-current generators. One cause of possible radio interference, from the generation of harmonics, is dependent upon the design characteristics of the generator. Squirrel-cage induction motors are not usually troublesome from a radio interference viewpoint if they are carefully designed for minimum generation of harmonics. However, alternating-current motors of the type that require commutators (example: universal motor used on AC) will be troublesome and should be avoided in applications where radio interference is a consideration.

b. SUPPRESSION.– Even with the best design and considerations, some radio interference may be generated by motors, generators, etc. In order to prevent this interference from being conducted or radiated to other equipment and thus cause malfunctioning, certain preventive measures may be taken. These are as follows:

(1) CLEANLINESS. – Keep the commutation surface clean and free from scores and pits, brushes well fitted and free in the brush holders, and the position of commutation adjusted so that minimum sparking occurs under full load conditions.

(2) ISOLATION. – Keep all conductors and cables, especially low-level cables, as far away as practical from any motors or generators. Some cases of interference may be reduced by simply rerouting cables in the vicinity of rotating electrical machinery.

(3) SHIELDING. – Clean all dust covers and other access plates of motors and generators of all insulating finishes where they mate with the main portion of the machine. In this manner, the metallic housing of the machine becomes a shield and is useful in reducing radiated interference. The brushes and brush leads are the most probable source from which interfernece may be radiated or coupled to other circuits. Therefore, unless the motor is completely enclosed, the brushes, and brush leads should be shielded as completely as possible. In the case of small DC machines, such as dynamotors, shielding should be complete. Ventilating holes should be fitted with screening (Figure 15-21).

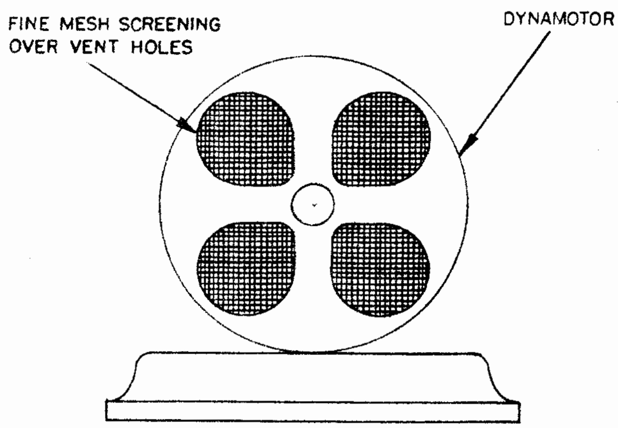


Figure 15-21. Shielding Vent Holes

(4) GROUNDING. - In cases where machinery frames, enclosures, or supports are not permanently grounded to the ship's structure, ground straps of flexible copper braid, not less than 1/2 inch wide, should be installed. The ground strap should be as short as possible with enough loop to allow for deflection of the entire structure under shock without impairing the action of the shock mounts. Connections should be locked to prevent loosening due to vibration. Only one strap should be used for each unit unless tests indicate more are needed. See Figure 15-22.

(5) FILTERS.- If the above methods do not suppress the radio interference to a tolerable level, filters must be installed. Filters are discussed in Chapter 21 of NavShips 900,171, but some of the considerations relating to motors and generators are summarized below.

If possible, the filter should be mounted directly on the frame of the interfering machinery. If space requirements make this impossible, the filter may be mounted away from the noise source provided the distance is held to a minimum and that the leads between the noise

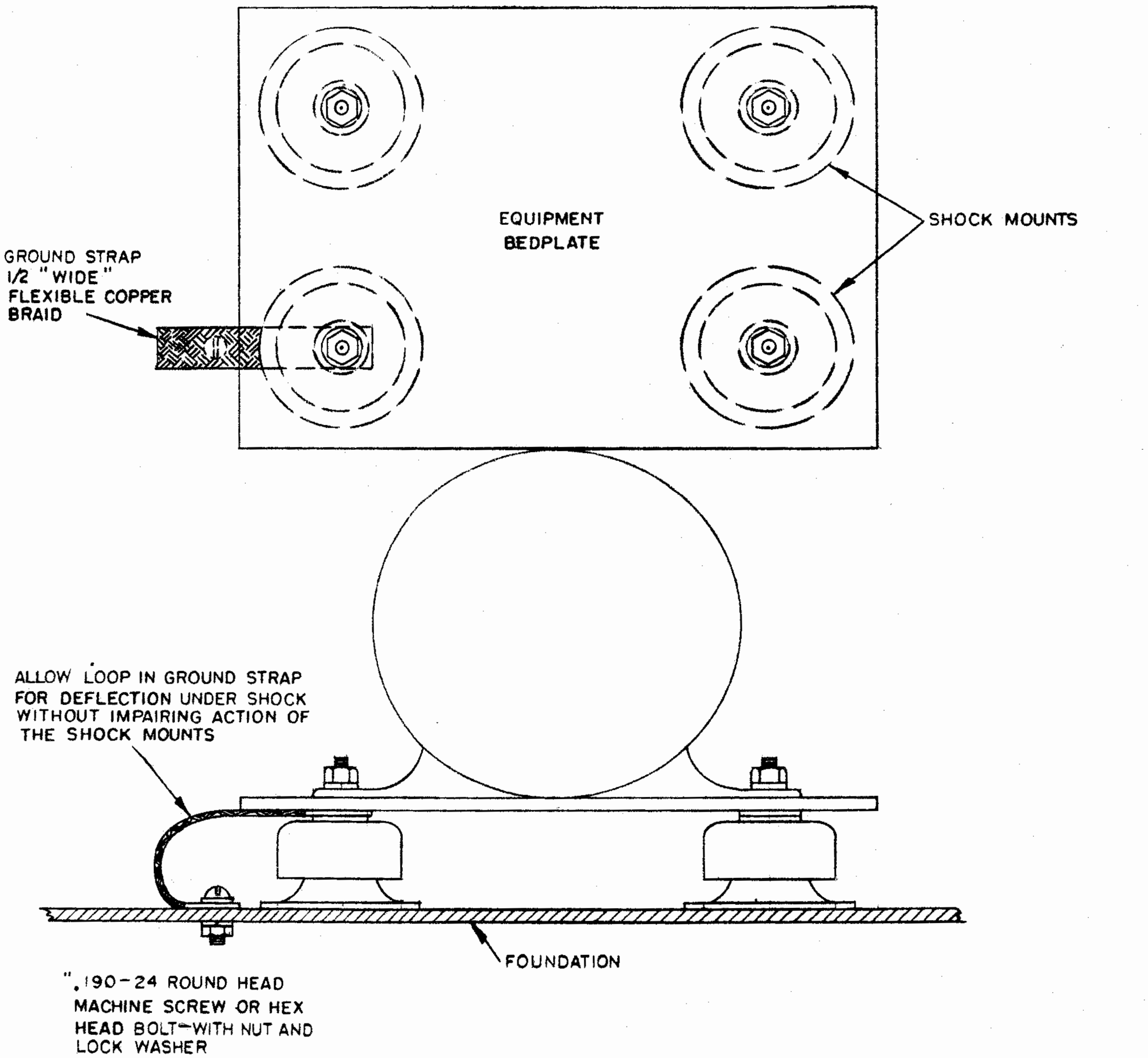


Figure 15-22. Method of Grounding Shockmounted Electrical Rotating Machinery

source and the filter are completely shielded. Make sure that the filter case is well grounded. Remove paint, if any, and scrape clean at those points where the filter is to be grounded. Use low-pass filters with proper voltage rating, current rating, attenuation and temperature rise. In all cases, the filter must withstand the test voltage of an insulation resistance tester (500 VDC). Filter selection should be based on a careful study of the requirements. (See Chapter 21, Filters.)

In some cases involving radio interference from brushes, a small capacitor of from 0.05 to 1.0 mf, depending upon the degree of interference, connected directly across the brushes with capacitor leads as short as is practical, may reduce the radio interference to a tolerable level if the unit is well shielded. When filters or capacitors are added to the alternating current portion of a small inverter, capacitance and inductance values used must be held to that minimum necessary to reduce the interference to a tolerable level in order that the output of the alternator is not affected.

(6) MECHANICAL CONSIDERATIONS.– Severe radio interference which increases from day to day is a sign of possible failure of the machine. Look for burnt commutator bars, loose commutator segments, loose brushes, loose bearings, and generally poor mechanical condition. As a general rule, any sudden increase in radio interference from rotating electrical machinery is a warning of a failure.

7. CONTROLLERS.

A controller is a device, or a group of devices, which serve to govern in some predetermined manner the electric power delivered to the apparatus to which it is connected.

A small portable motor may be connected to the line by a simple cord and plug, and the motor may be turned on or off by a switch attached to the motor. Switching is not so simple in the case of larger motors. The high-starting current of large motors makes it necessary to limit this current. It is also desirable to protect the motor against electrical and mechanical overloads. It may be desirable to have additional control over the motor, such as direction of rotation, speed control, remote operation, low-voltage protection, etc. Therefore, a large variety of controllers are available to meet the requirements for a specific installation. See Table 15-2 for controller sizes vs horsepower rating.

a. OPERATION. – Controllers are classified as to method of operation as follows:

(1) MANUAL. – A manual controller is one in which the main contacts are operated by a mechanical system which, in turn, is actuated directly by the operator.

(2) MAGNETIC. – A magnetic controller is one in which the main contacts are operated by an electromagnetic device. These devices are usually governed by master switches located at the controller and/or at some remote location.

b. TYPE. – Controllers are classified as to type as follows:

(1) ACROSS-THE-LINE. – This controller consists of devices for connecting the motor directly across the line at full-line voltage.

(2) RESISTOR. – This controller inserts a current-limiting resistor in the armature circuit during the starting period, thereafter short circuiting the resistor to apply full voltage to the armature after the starting cycle is completed.

(3) ADJUSTABLE VOLTAGE. – In this controller, the armature voltage may be varied, smoothly or in small increments, as a means of controlling the speed of the motor. An autotransformer is used to reduce the line voltage for starting large AC motors.

TABLE 15-2. CONTROLLER SIZE VS HORSEPOWER RATING

AC CONTROLLERS

Standard Voltage	
Single Phase	Three Phase
115	110
230	220
440	440

Size No.	Ampere Rating of Line Contactor	Maximum Horsepower					
		110V 3 phase	115V 1 phase	220V 3 phase	230V 1 phase	440V 3 phase	440V 1 phase
0	15	1-1/2	1	2	1-1/2	2	1-1/2
1	25	3	1-1/2	5	3	7-1/2	5
2	50	7-1/2	3	15	7	25	10
3	100	15	7-1/2	30	15	50	25
4	150	25	---	50	---	100	---
5	300	---	---	100	---	200	---

DC CONTROLLERS

Standard Voltage
115
230

Size No.	Ampere Rating of Line Contactor	Maximum Horsepower	
		115V	230V
0	15	1/2	1/2
1	25	3	5
2	50	5	10
3	100	10	25
4	150	20	40
5	300	40	75
6	600	75	150

c. PERFORMANCE. - Controllers are classified as to performance as follows:

(1) NON-AUTOMATIC. - The non-automatic controller is a manual controller.

(2) SEMI-AUTOMATIC. - The semi-automatic controller is a magnetic controller in which all functions are governed by one or more manual master switches.

(3) AUTOMATIC. - An automatic controller is a magnetic controller in which any of the functions are governed by one or more automatic switches after the controller is first energized by the operation of a manual master switch.

8. MOTOR DRIVE COUPLING.

The mechanical connection between the motor and the driven mechanism depends upon many factors. The more common methods of drive are summarized as follows:

a. BELTS. - Belts are the most common and usually the cheapest means of driving machinery. They have the disadvantage of being elastic and capable of stretching, causing slipping. Under some unsteady load conditions, belts will come off. They are not desirable for use at high speeds.

b. "V" BELTS. - For close center drives, "V" belts are used to good advantage. Because of the size and shape of the "V" belts and their clinging action to sheaves or pulleys, they can be used for fairly high ratios without slipping.

c. CHAIN BELTS. - Chain belts are positive, and are useful for short-center drives. They will not slip. Sometimes they are noisy and require lubrication.

d. GEARING. - For high ratios, high speeds, and close quarters, gears are generally desirable. This requires rather rigid supports for motor and driven machines and fairly accurate alignment. The different types of gears used with motors are: spur, herring bone, worm, spiral, helical, and bevel. The name "speed reducer" is commonly used for special speed-changing gear sets. They are designed to give a wide range of speeds and are housed in a self-contained enclosure ready for connection between the motor and the driven machine.

e. DIRECT DRIVE. - Direct drive through a flexible coupling makes the neatest and simplest installation where the motor speed is the same as that of the driven machine: however, it requires careful alignment. For high speeds, direct drive is almost universal.

f. FRICTION CLUTCHES AND MAGNETIC CLUTCHES. - These are sometimes used with synchronous and other types of motors that have relatively low starting torques. The motor is first brought up to speed without load and then the load is gradually connected to it by means of the clutch. For large loads it may be difficult to operate a friction clutch, where a magnetic clutch can be operated by electrical control. Magnetic clutches need direct current for operation and with synchronous motors, this is available from the source of excitation.

9. GENERAL NOTES.

a. STANDARD DIRECTIONS FOR ROTATION OF MOTORS AND GENERATORS. - The standard direction for rotation of generators is clockwise and that of all motors except polyphase motors is counterclockwise as viewed from the front (the "front" of a normal motor or generator is the end opposite the drive shaft). The commutator or slip rings are usually at the front end. Polyphase motors are not included because their direction depends upon the order followed in connecting up the different phases in the power supply circuits.

b. METHODS OF CHANGING MOTOR ROTATION.

(1) DIRECT-CURRENT MOTORS. - Direction of rotation may be changed in

a series or shunt-type motor by reversing the connections to either the field or the armature but not to both. Compound-motor rotation is reversed by interchanging armature connections or shunt and series-field connections. For example, if only the shunt-field connections were reversed on a cumulative-compound motor, the motor rotation will be reversed, but the motor will then operate as a differential-compound motor. If the motor is not equipped with commutating poles, the brushes should be shifted to the same position on the opposite side of the neutral axis. It should be noted that reversal of the line terminals has no effect on the direction of rotation of a direct-current motor.

(2) ALTERNATING-CURRENT MOTORS. - To reverse direction of rotation of a two-phase, four-wire motor, the connections to one phase must be interchanged. In a two-phase, three-wire motor, the two outside leads should be interchanged to change rotation. In a three-phase motor, it is only necessary to interchange two of the phases.

In a single-phase, repulsion-start induction motor, direction of the rotation is changed by shifting the brushes according to marks that the manufacturer has made on the motor frame or brush holder. In other types, the instructions of the manufacturer should be followed.

It should be noted that reversal of the line terminals does not affect the direction of rotation of a single-phase motor.

SECTION 15-2

INSTALLATION

1. LOCATION

Care should be taken when installing a motor or generator to choose a location where there is sufficient clearance around the unit for maintenance purposes. At least 18 inches clearance should be allowed on the top and sides for removal of any components and for routine maintenance. These clearances will vary with the different types of units.

If possible, motors, generators, and motor-generator sets should not be installed in a radio room.

The unit should be mounted so that the shaft is parallel to the center line of the ship; that is, fore and aft rather than athwartship. Mounting motors athwartship would subject bearings to excessive wear since most ships exhibit more roll than pitch when underway.

If machinery is not to be installed immediately, it should be stored in a clean, dry place and protected from low temperatures, sudden changes in temperature and high humidity.

2. HANDLING AND LIFTING.

Whenever it becomes necessary to disassemble and reassemble a motor or generator for installation, maintenance or other reasons, the procedure outline in the manufacturers' instruction books should be followed.

Motors, generators and amplidynes should be handled carefully to prevent damage to any part. On large units the rotors should be supported while being moved, or when stationary, by slings or blocking under the shaft, or by a padded cradle or thickly folded canvas under the core laminations. When lifting the rotor, use rope slings under each end of the shaft and use a spreader between the slings to prevent their coming in contact with the AC or DC armature.

In moving any of the parts, take care that the windings are not bumped against anything that is liable to damage the insulation.

Remember that by rough handling or careless use of bars or hooks, it is possible to do more damage to a machine than it will receive in years of regular service.

Eyebolts and other means of suitable size and strength are provided for the lifting of heavy units. THESE EYEBOLTS ARE NOT TO BE USED FOR THE LIFITING OF A MOTOR-GENERATOR SET. THEY ARE FOR THE LIFTING OF THE SEPARATE UNITS ONLY. Motor-generator sets are lifted by means of slings placed under the bedplate. This method of lifting does not disturb the alignment of the separate units on the bedplate.

3. MOUNTING.

a. GENERAL. - Motors, generators, motor-generator sets and amplidynes are erected on foundations sufficiently stiff to insure freedom from vibration.

The type unit to be mounted, its size, weight and location determines the type of foundation to be used.

There are two types of mounting used; rigid mounting and shock mounting. Rigid mounting is generally used except in cases where severe shock or sound isolation are considerations.

Mounting dimensions and other useful details for mounting are shown in plan drawings. The unit is lifted on the foundation and put into its mounting position. The positions for the securing bolts are then marked to match up with the bolt holes on the mounting feet or the bedplate. The unit is then removed and the holes are drilled. An air or electric drill may be used to drill the bolt holes. See Tables 15-3 and -4.

TABLE 15-3. PNEUMATIC DRILLS

Size (in)	Morse Taper Socket No.	Non-reversible SNSN (a)	Reversible SNSN (b)
1/4	Chuck	G40-D-433	G40-D-448
1/2	1	G40-D-435	---
7/8	2	G40-D-437	G40-D-451
1-1/4	3	G40-D-439	G40-D-453
2	4	G40-D-441	G40-D-455
3	5	G40-D-443	G40-D-457

TABLE 15-4. PORTABLE ELECTRIC DRILLS

Max Drill Size (in.)	Chuck or Morse Taper No.	SNSN
1/4	Chuck	G40-D-351-50
1/4	Chuck	G40-D-339-5
1/4	Chuck	G40-D-341
3/8	Chuck	G40-D-343
1/2	Chuck	G40-D-345
3/4	Morse No.2	G40-D-346

When the holes have been drilled the unit is lifted onto the foundation and placed so that the mounting bolt holes are aligned with the foundation bolt holes. If the entire unit is not level on the foundation, it must be shimmed until level. (Alignment procedure is covered in a following section.) When the unit is level, the bolts are then inserted and tightened uniformly. To remove any unit from its foundation:

(1) Disconnect all wiring.
(2) Rig a sling to allow safe handling of the unit.
(3) Remove the hold-down bolts.
(4) Lower the unit to the deck.
(5) Mark all shims so that they may be replaced in their original position.

The bolts used to secure the unit to the foundation vary in size. Appropriate lockwashers and nuts should be used to guard against loosening due to vibration.

b. FOUNDATIONS. - The foundations are made usually from medium steel in the form of angle iron, I beams, tees or channels. All parts of the foundation are welded together. The foundations are welded to a steel deck or bulkhead and riveted to an aluminum deck or bulkhead. A typical foundation rack is shown in Figure 15-23 on which three units may be mounted.

The rack consists of four vertical angle irons welded to the deck at the corners of the foundation. Angle irons are welded between these to form mounts and the unit is braced by two angle irons starting from the middle of the foundation to the deck. A deck mounting angle iron foundation is provided between the legs of the rack. Mounting holes are then drilled from a template of each unit.

Care must be exercised when choosing the type of foundation material to be used. It must be heavy enough to withstand the weight of the machinery and yet must not be excessively heavy since extra weight is undesirable.

Lists of angles, I beams, tees and channels which may be used for foundations and their Navy Stock Numbers are shown in Tables 15-5, -6, -7 and -8.

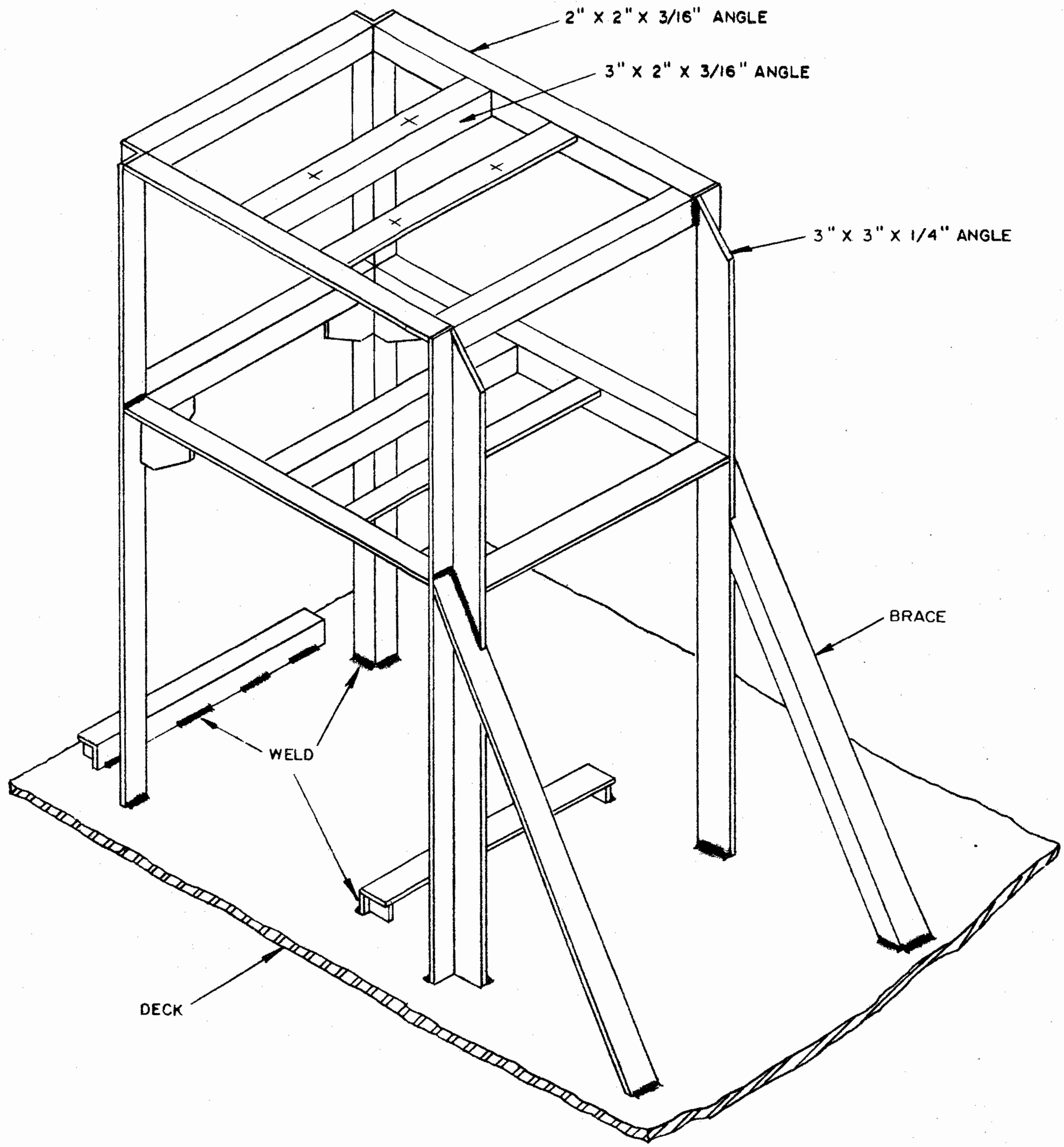


Figure 15-23. Three-Unit Foundation Rack

TABLE 15-5. ANGLES

Dimensions (in.)			Lbs. per foot	SNSN
X	Y	Z		
2	1-1/2	1/8	1.44	G48-A-1212
2	1-1/2	3/16	2.12	G48-A-1215-10
2	1-1/2	1/4	2.77	G48-A-1215-50
2	2	3/16	2.44	G48-A-1220
2	2	1/4	3.19	G48-A-1230
2-1/2	1-1/2	3/16	2.44	G48-A-1240-20
2-1/2	1-1/2	1/4	3.19	G48-A-1240-30
2-1/2	2	3/16	2.75	G48-A-1250
2-1/2	2	1/4	3.62	G48-A-1250-30
2-1/2	2	5/16	4.50	G48-A-1250-40
2-1/2	2-1/2	3/16	3.07	G48-A-1259
2-1/2	2-1/2	1/4	4.1	G48-A-1260
2-1/2	2-1/2	5/16	5.0	G48-A-1270
2-1/2	2-1/2	3/8	5.9	G48-A-1270-10
3	2	3/16	3.07	G48-A-1275-10
3	2	1/4	1.44	G48-A-1275-20
3	2	5/16	5.0	G48-A-1275-40
3	2	3/8	5.9	G48-A-1275-50
3	2-1/2	1/4	4.5	G48-A-1280
3	2-1/2	5/16	5.6	G48-A-1290
3	2-1/2	3/8	6.6	G48-A-1290-155
3	3	1/4	4.9	G48-A-1296
3	3	5/16	6.1	G48-A-1300
3	3	3/8	7.2	G48-A-1310
3	3	1/2	9.4	G48-A-1310-20
3-1/2	2-1/2	1/4	4.9	G48-A-1315
3-1/2	2-1/2	3/8	7.2	G48-A-1315-60
3-1/2	3	5/16	6.6	G48-A-1320
3-1/2	3	3/8	7.9	G48-A-1330
3-1/2	3-1/2	5/16	7.2	G48-A-1339-40
3-1/2	3-1/2	3/8	8.5	G48-A-1339-60
3-1/2	3-1/2	1/2	11.1	G48-A-1340
4	3	1/4	5.8	G48-A-1349-80
4	3	5/16	7.2	G48-A-1350
4	3	3/8	8.5	G48-A-1360
4	3-1/2	3/8	9.1	G48-A-1370
4	3-1/2	1/2	11.9	G48-A-1380
4	4	1/4	6.6	G48-A-1385
4	4	5/16	8.2	G48-A-1386
4	4	3/8	9.8	G48-A-1387
4	4	1/2	12.8	G48-A-1390
5	3-1/2	5/16	8.7	G48-A-1397
5	3-1/2	3/8	10.4	G48-A-1400

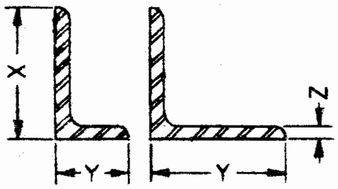


TABLE 15-6. STEEL CHANNELS

Nominal Size (inches)		Thickness (inches)		Lbs. per foot	SNSN
Depth	Flange	Web.	Flange		
3	1-3/8	0.170	0.273	4.1	48-C-540
3	1-1/2	0.258	0.273	5.0	48-C-545-50
3	1-1/2	0.356	0.273	6.0	48-C-545-60
4	1-5/8	0.180	0.296	5.4	48-C-550
4	1-5/8	0.247	0.293	6.25	48-C-550-20
4	1-5/8	0.320	0.296	7.25	48-C-550-40
5	1-3/4	0.190	0.320	6.7	48-C-570
5	1-3/4	0.325	0.320	9.0	48-C-570-10

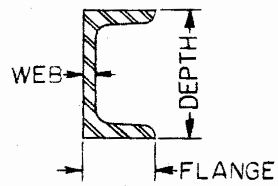


TABLE 15-7. I BEAMS

Nominal Size (inches)		Lbs. per foot	SNSN
Depth	Flange		
3	2-3/8	5.7	48-I-390-5
3	2-3/8	7.5	48-I-390-225
4	2-5/8	7.7	48-I-395
4	2-5/8	9.5	48-I-395-50
5	3	10.0	48-I-400
6	3-3/8	12.5	48-I-410
6	3-3/8	17.2	48-I-410-50
7	3-5/8	15.3	48-I-415
8	4	18.4	48-I-420
10	4-5/8	25.4	48-I-425

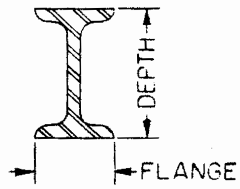
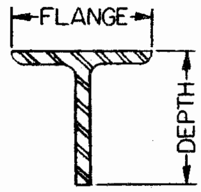


TABLE 15-8. TEES (MEDIUM STEEL)

Size (inches)		Thickness		Lbs. per foot	SNSN
Depth	Flange	* Stem	Flange		
3	3.00	3/8	3/8	7.8	48-T-310
2-1/2	4.00	3/8	3/8	8.5	48-T-335
3	4.00	3/8	3/8	9.2	48-T-340
5	4.00	0.230	0.269	7.5	48-T-351-50
5	4.00	0.240	0.329	8.5	48-T-351-60
6	4.00	0.230	0.269	8.2	48-T-353-60
6	4.00	0.260	0.424	11.0	48-T-353-80
5	4.66	0.310	0.491	12.7	48-T-354-80
3	5.00	3/8	3/8	11.5	48-T-360



c. MOUNTING CONSIDERATION.

(1) SHOCK MOUNTS. – Shock mounts for Naval shipboard use are designed to protect equipment from the severe shocks which occur during service and to provide general sound or vibration isolation. Shock damage is prevented by the mount which stores the energy of the shock and releases it at a slower rate. Vibration isolation is accomplished by mounts which have a different natural frequency than the frequency of vibration to be isolated. Vibration isolation is a very important consideration in submarine applications and is discussed under sound isolation in paragraph 3c (2), following. Selection of the correct shock mounts for a particular installation, therefore, is based on the necessity of providing protection from high impact shock forces and at the same time to provide enough stiffness to avoid resonance with the steady vibration aboard ship. When shock mounts are used on motors, generators, motor-generator sets, or amplidynes, they are usually inserted between the bedplate and the foundation. In most cases the type and size shock mount will be specified. The weight of the unit is a deciding factor in the selection of size. For this reason, additional components should not be mounted on shockmounted equipment, and different items of shockmounted equipment should not be stacked on top of one another. Figures 15-24 thru 15-29 show types of shock mounts now being used on equipments being installed aboard ship. These types are designed primarily for absorption of high impact shock and general sound isolation.

In regard to shock mount installation the following precautions should be observed:

(a) Do not make changes or alterations which will decrease the clearance provided when shockmounted equipment is installed in order to allow for its movements on the shock mounts.

(b) Mask all shock mounts at installation and remove the masking after all painting has been completed. Rubber resilient elements of mounts should not be painted.

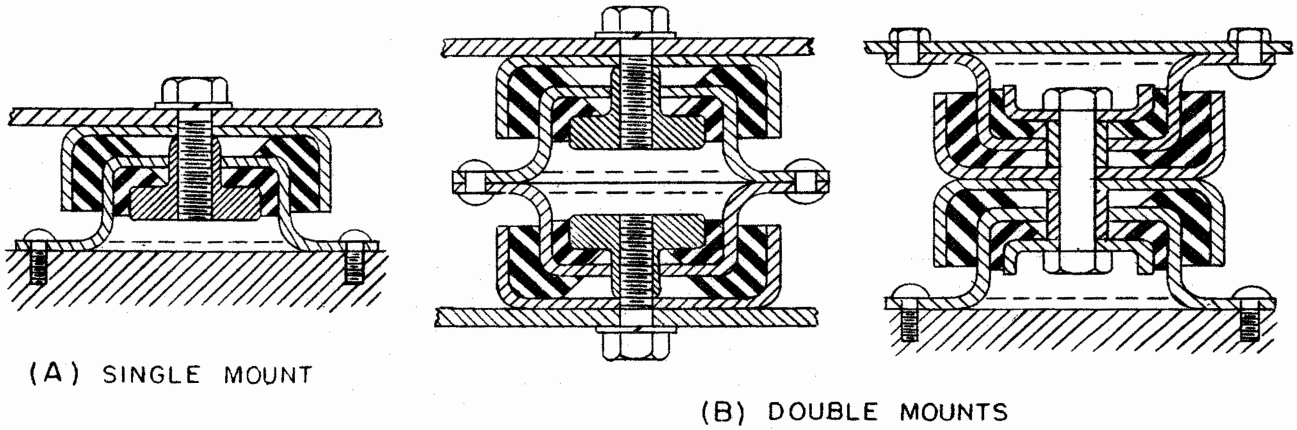


Figure 15-24. Cup-Type Mounts

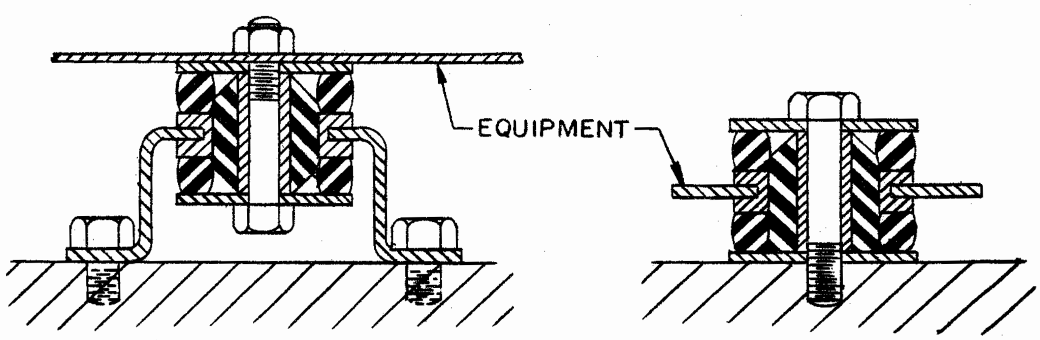


Figure 15-25. Button-Type Mounts

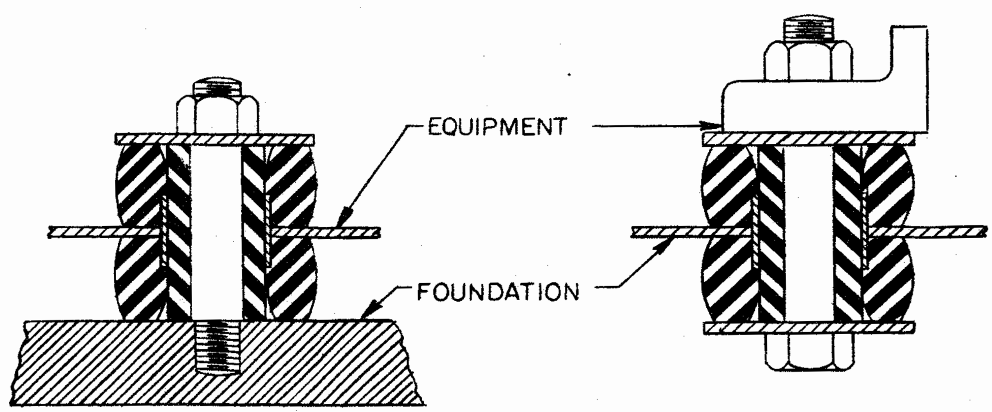


Figure 15-26. Portsmouth-Type Mounts

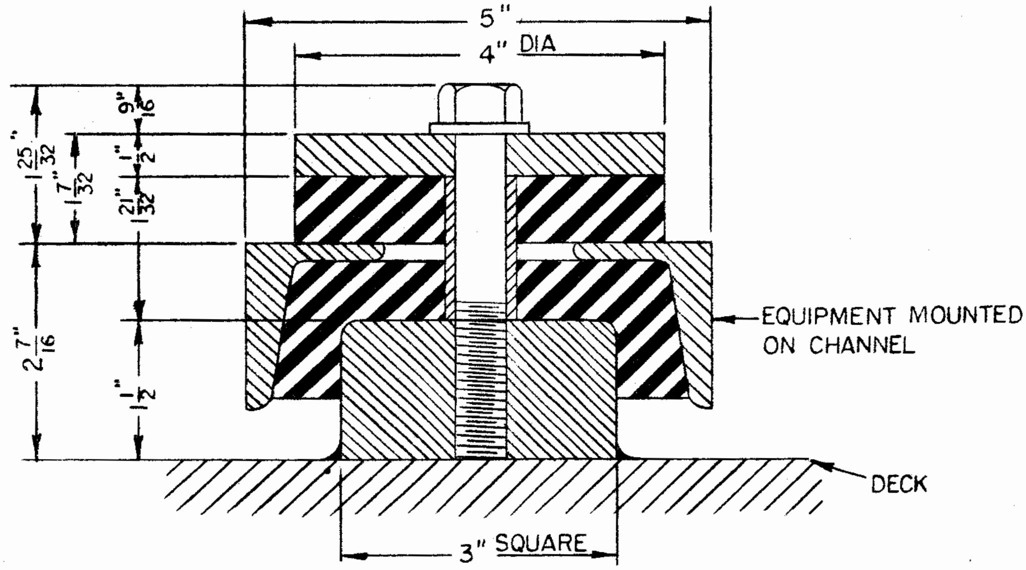


Figure 15-27. Channel Mount

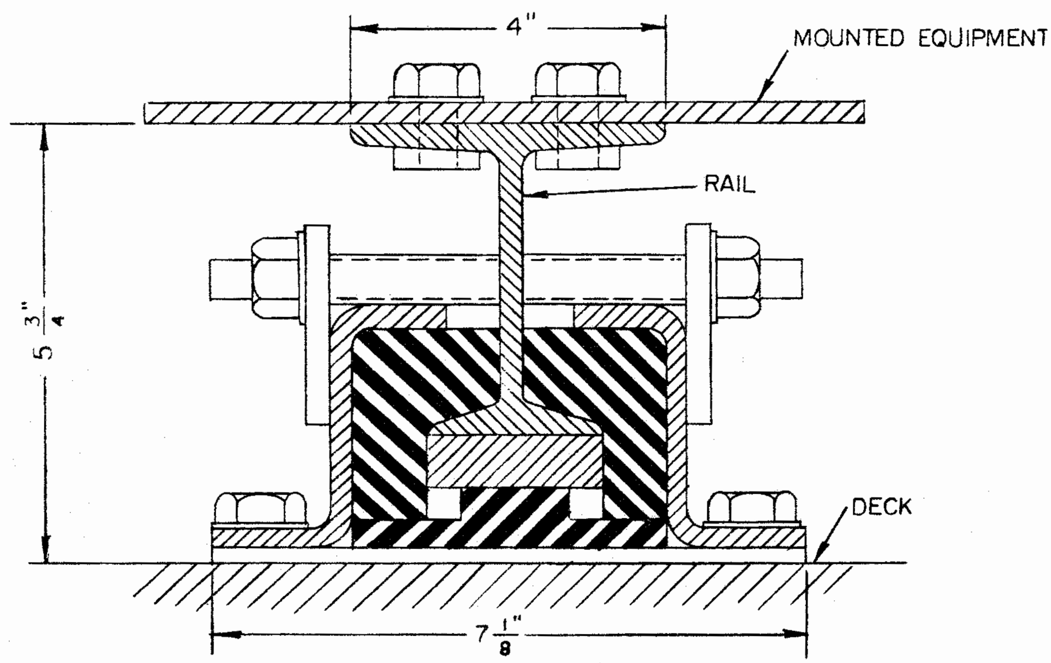


Figure 15-28. Rail Mount

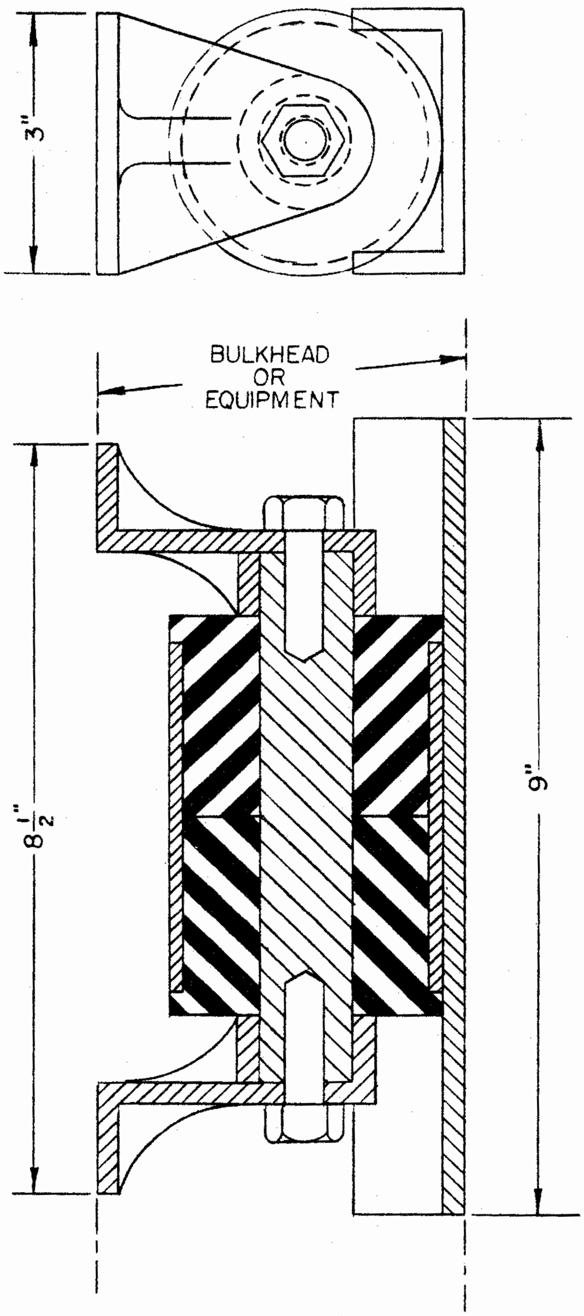


Figure 15-29. Top Brace Mount

(c) Any welding which is to be done in the vicinity of a shock-mount installation, should be performed before the shock mounts are installed.

(d) Foundations should be accurately aligned to mounting bolt centers so as to prevent any distortion of the mount.

(e) Make sure that all cables, ground straps, or flexible pipe connectors have enough slack to allow for movement of the equipment on the mounts under shock conditions.

(f) All shock mounts should be jumped to ground by means of a flexible copper braid strap, not less than 1/2" wide. The strap should be as short as possible with only enough loop allowed to permit satisfactory deflection of shock or isolation mounts. A good metal contact should be made on all grounds. All paint or foreign material which may prevent a good RF ground should be removed. Connections should be locked to prevent loosening due to vibration.

In mounting rotating machinery such as motor generator sets where sound isolation is important, great care must be used to insure that the machinery does not have a natural frequency on its mounts which is equal to the frequency of vibrations present aboard ship and those vibration frequencies resulting from the rotating machinery. Mounts are used having a stiffness considerably lower than that required for maximum shock protection. When this is done, there is some reduction in shock protection and possible resonance with shipboard forcing vibrations is risked.

(2) SOUND ISOLATION. - Vibration is a continuing periodic motion caused by an oscillating force. The force may be the result of mechanical movements such as a reciprocating mass or an unbalanced mass. It may also be the result of an electrical disturbance such as a fluctuating magnetic force. The problem that arises aboard submarines involves the isolation of the vibration force. Electric motors are commonly mounted upon vibration isolators or

mounts to prevent transmission of vibratory forces to structural members or the hull where they may interfere with sound detection devices or themselves be a source of sound for detection. This sound arises from the vibration of surfaces in contact with air or water.

Vibration control is achieved by three different procedures. The source of vibration may be altered by design changes; the transmission path by which the vibration is propagated from the source may be reduced in effectiveness by isolation mounts; or the sound level produced may be reduced through the process of "quieting". Shipboard installation concerns the last two procedures.

Quieting provides a high degree of sound absorption at all interior reflecting surfaces exposed to the noise. Commercially available sound absorbing materials such as Fiberglas Acoustic Tile, and Acousti-Celotex are cemented to flat surfaces or secured to metal furring strips. Figure 15-30 shows an application where acoustical absorbing material (Military Specification MIL-B-15365) is applied to five sides of a frame enclosing a motor-generator set and amplidyne assembly. The acoustical absorbing material is sandwiched between aluminum sheets riveted together except where the material is in contact with the bulkhead or the overhead. In this case, aluminum sheeting is applied on the side exposed to the sound. The

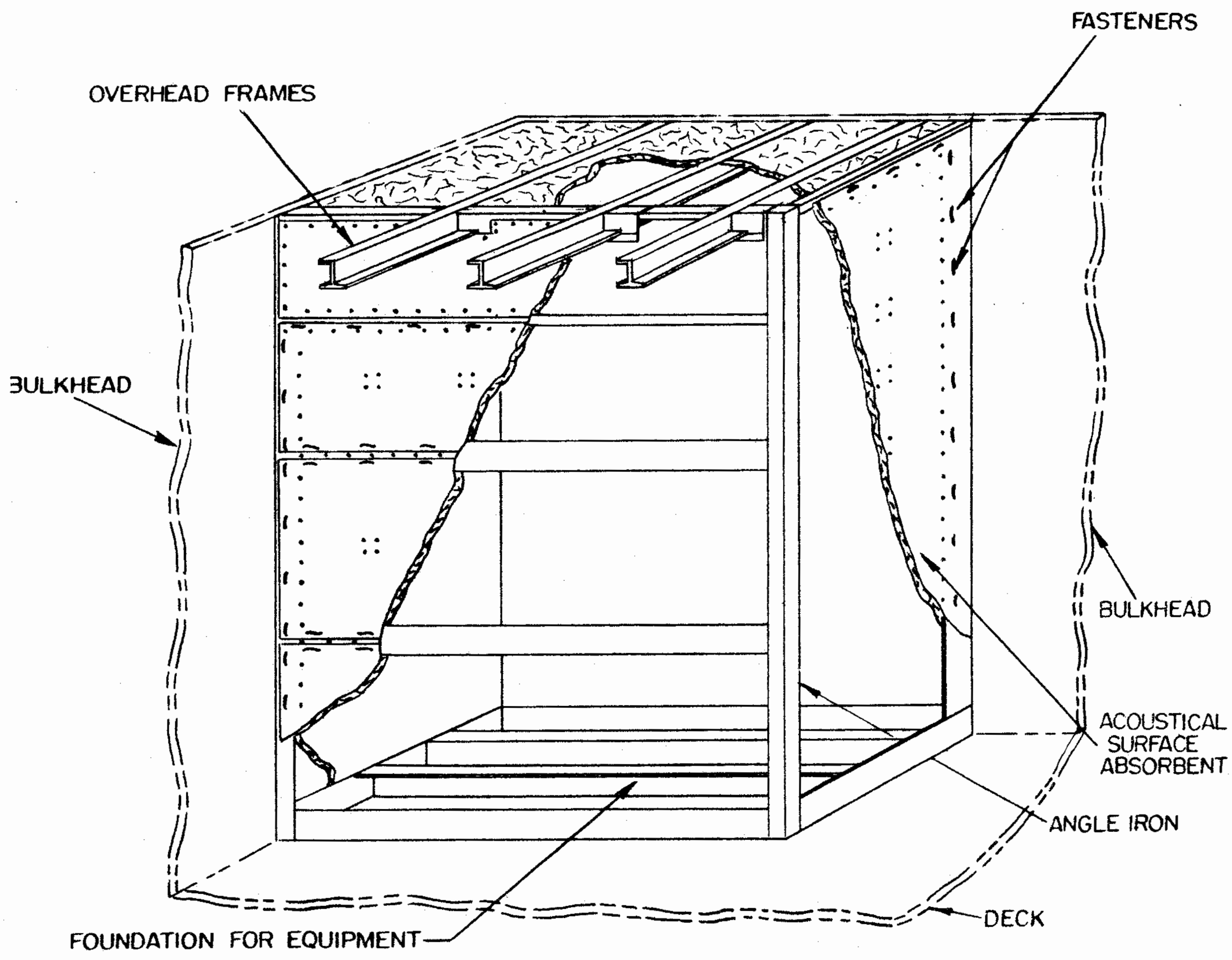


Figure 15-30. Acoustical Absorbing Shield

material is attached to the framework in sections by fasteners for easy removal.

In this connection, it should be noted that the use of common acoustical surfaces absorbents for reduction of sound radiation from vibrating surfaces is not effective except for absorption of the sound after it has been radiated.

Sound measurements are usually carried out by means of a sound-level meter comprising a microphone, amplifier and a decibel meter. Sound-level surveys are useful in inspection tests for a completed installation.

(3) ALIGNMENT.—One of the biggest problems in dealing with motor-generator sets is the alignment problem. Without proper alignment, the set will not operate properly and excessive damage to the units may result.

All motor-generator sets are mounted on a bedplate and they must be perfectly aligned on this bedplate before installation. When there are two machines to be aligned, one of the machines should be bolted and doweled securely to the bedplate. The other should be put into position and shimmed until its shaft is even with the shaft of the first unit. This may be determined by using a straight edge and a level. When the level position has been found, the unit should be doweled and bolted securely to the bedplate, and the shaft coupling attached.

When three units are to be secured to a bedplate, one unit should be securely bolted and doweled to the center of the bedplate and the other units mounted on either side and shimmed until they are level. They are then doweled and bolted securely to the bedplate.

The shims are inserted under the feet of the motor or generator and are made of either steel or brass. Steel is used as a shim where a large shim is needed. Brass shims are usually used where a very narrow shim is needed. Brass shims are listed in Table 15-9.

TABLE 15-9. DIMENSIONS AND STOCK NUMBERS FOR BRASS SHIMS

Overall Dimensions (In Inches)			SNSN
T	W	L	
0.020	6	36	47-B-1051-100
0.020	8	36	47-B-1051-110
0.062	6	36	47-B-1051-300
0.062	8	36	47-B-1051-310
0.094	6	36	47-B-1051-500
0.094	8	36	47-B-1051-510

All types of mitre dowels are used. Dowels 1/2 inch or more in diameter are provided with threads and nuts. Taper dowels may be used for size 3/8 inch and smaller. All diameters refer to the small end of the dowel. Dowels should be located so as to be easily removable when a unit is removed from the bedplate.

The bolts used to secure the feet of the unit to the bedplate vary in size according to the type of the unit being mounted. They are standard hexagon head bolts and vary from 1/4 inch to 3/4 inch. They may be tightened by using any box, socket or open end wrench that fits the bolt correctly.

The alignment should be rechecked after units have been moved.

d. TYPICAL MOUNTING ARRANGEMENTS.

(1) DECK MOUNTING. — Motors, generators, motor-generator sets and amplidynes may be deck mounted, overhead mounted, shelf mounted, etc.

If the machinery is to be deck mounted, I-beams, angles, or channels are used as foundations and are welded to the deck. In some cases, the deck on which the unit is mounted must be strengthened by welding stiffeners to the underside of the deck. Typical deck mount arrangements are shown in Figures 15-31, -32, and -33. Bedplates are usually supplied with motor-generator sets and holes are usually provided to prevent accumulation of dust and oil.

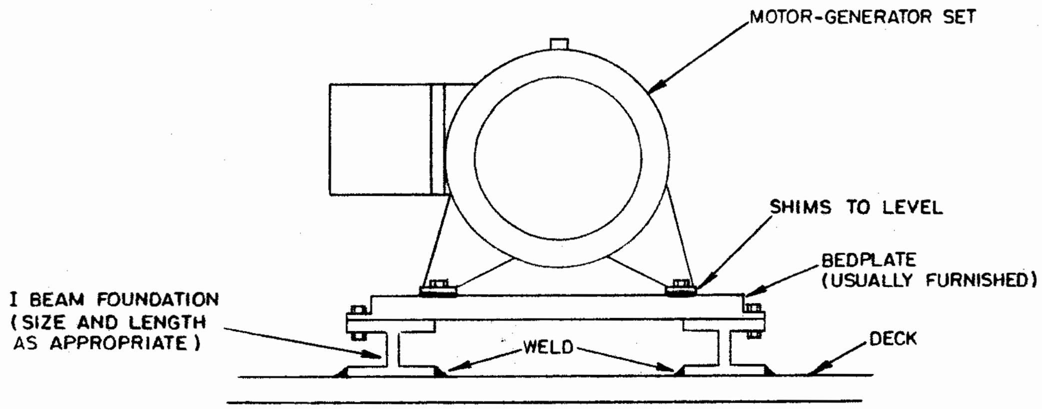


Figure 15-31. I Beam Foundation, Rigid Deck Mount

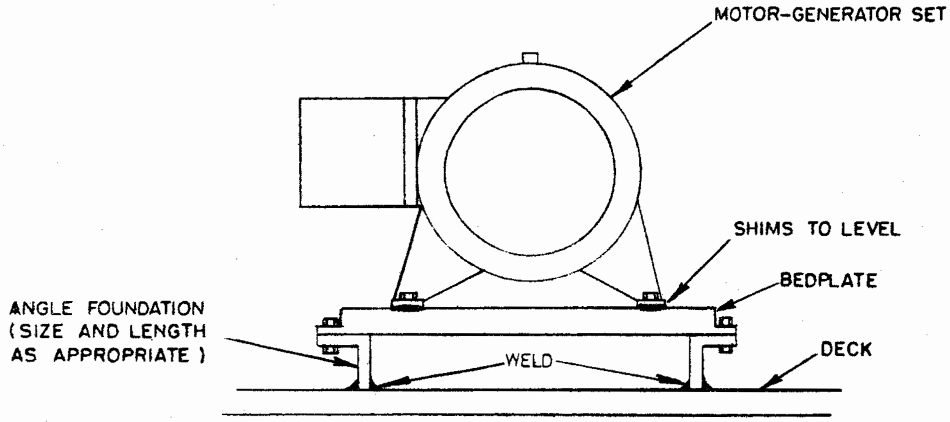


Figure 15-32. Angle Foundation, Rigid Deck Mount

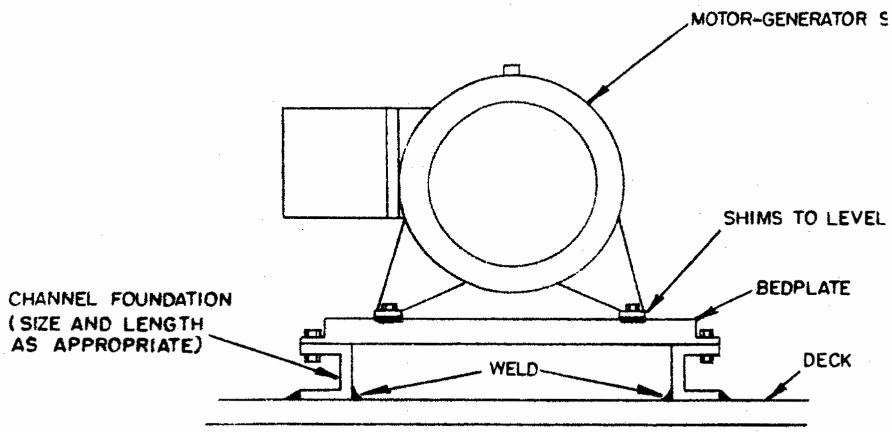


Figure 15-33. Channel Foundation, Rigid Deck Mount

(2) OVERHEAD MOUNTING. - Motor generators,etc., are usually not mounted on an overhead unless the unit is small and of light weight and space considerations demand it. Figure 15-34 shows an example of rigid overhead mounting. Note that lubrication pipes or holes must be arranged to retain lubrication. This may be done by rotating the end bell if possible or arranging a pipe as shown in phantom in Figure 15-34.

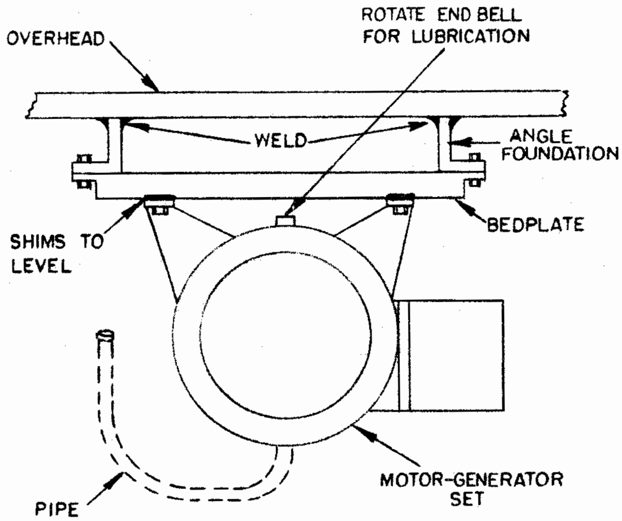


Figure 15-34. Rigid Overhead Mounting

(3) SHELF MOUNTING. - In order to mount a motor-generator set or similar unit on a slanted bulkhead, a shelf foundation is often used. The shelf foundation may take the form of two flange plates with an angle iron welded between them. The flange plates are welded to the bulkhead with the flange uppermost and horizontal. The angle iron is welded between the flange plates, parallel to the bulkhead. The mounting holes are drilled in the horizontal flanges from a template of the bedplate of the unit. Figure 15-35 shows a shockmounted unit mounted on a slanting bulkhead.

(4) MISCELLANEOUS. - Many times, because of existing structures or to conserve deck area, it is necessary to mount motor-generator sets and similar units one above the other. In a typical case this may be done by deck mounting one unit in a corner close to a bulkhead and by mounting the other unit on a shelf welded to the two bulkheads above the first unit.

The foundation for the deck-mounted unit (as shown in Figure 15-36) consists of two angle irons which are welded at one end to the bulkhead and which are supported between mounting holes by means of tilt brackets. The mounting holes are then drilled from a template.

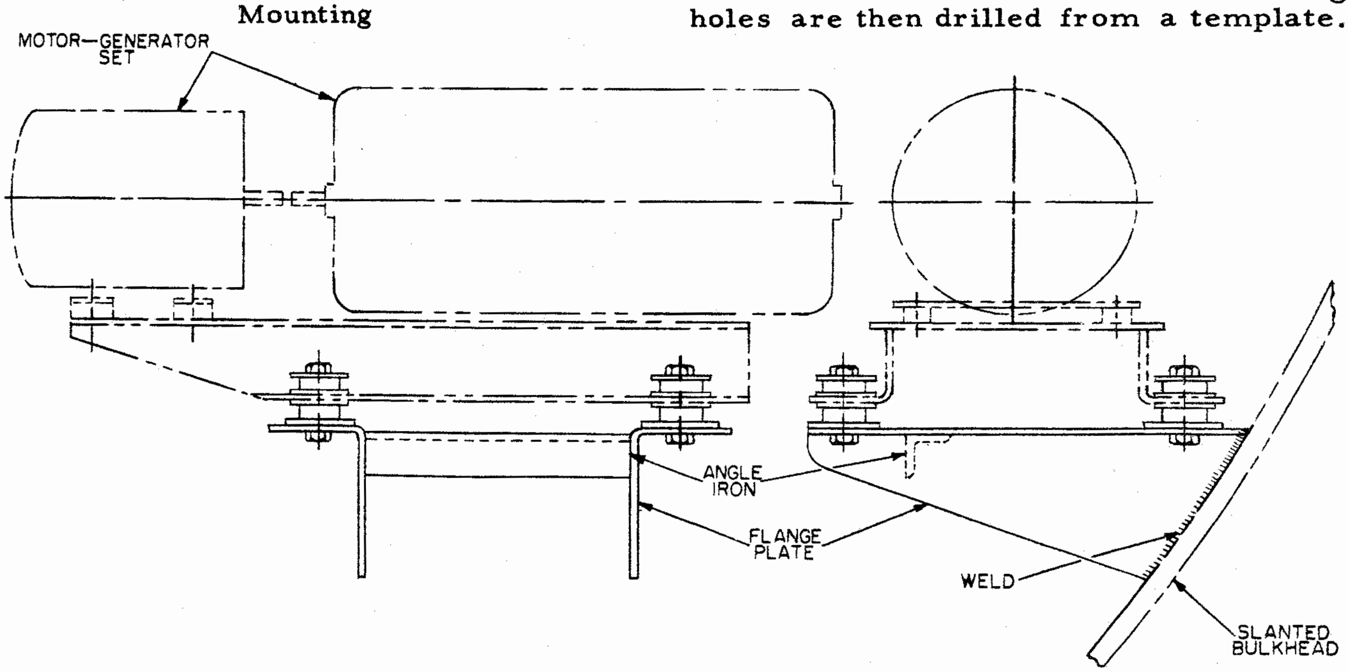


Figure 15-35. Mounting on a Slanting Bulkhead

The foundation for the shelf-mounted unit (Figure 15-36) consists of a flange plate placed in the corner horizontally and welded to the bulkhead along two edges and of another flange plate placed vertically between the mounting holes beneath the shelf and welded to the bulkhead and to the shelf. The mounting holes are then drilled on the horizontal plate from a template.

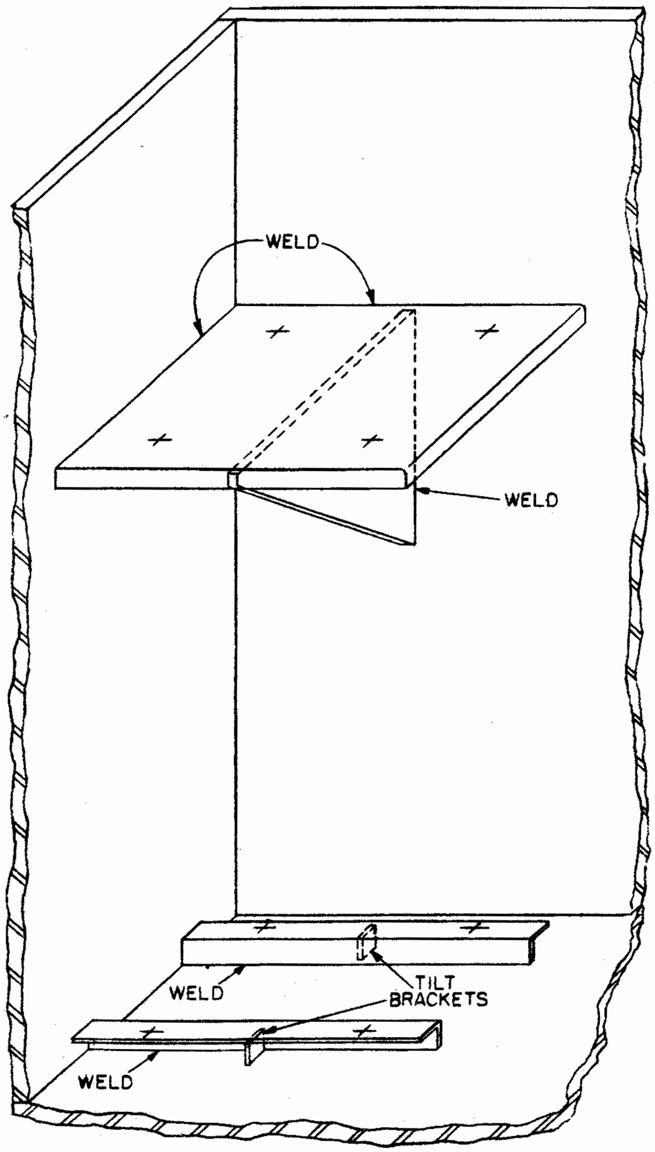


Figure 15-36. Deck and Shelf Mounting

4. ELECTRICAL CONNECTIONS.

Loose connections result in increased contact resistance and increased heating which may result in a breakdown. Use locknuts, lockwashers, or other means to lock connections which tend to become loose because of vibration. Inspect soldered terminal lugs for looseness or loss of solder and tighten solderless terminal lugs occasionally.

When electrical connections are opened, clean all oil and dirt from contact surfaces before reconnecting. If the contact surfaces are unplated copper, sandpaper and clean immediately before joining. If the contact surfaces are silver plated, do not use sandpaper, use silver polish or a cloth moistened slightly with carbon tetrachloride. Steel bolts used for making electrical contact should be zinc or cadmium plated.

The terminal markings for motors, generators, and amplidynes consist of a capital letter of the alphabet followed by a subscript Arabic numeral. The letters and numerals are permanently marked and are of a size that is clearly legible.

Terminal markings are assigned to different types of windings and their functions. The following markings indicate the character of function of the winding which is brought to the terminal:

Brush on commutator (armature) .... A1, A2, A3, etc.

Brush on collector ring (except DC field) for AC only ...... M1, M2, M3, etc.

Field (commutating) C1, C2

Field (Series) S1, S2

Field (shunt) F1, F2

Line .... L1, L2, L3, etc.

Resistance (armature and miscellaneous) R1, R2, R3, etc.

Resistance (shunt field adjusting) .... V1, V2, V3, etc.

Stator (for AC only) . . . . T1, T2, T3, etc.

5. INSTALLATION TESTS.

a. PRECAUTIONS. - After installation and before placing into service, each motor, generator, motor-generator set and amplidyne should be subjected to a careful examination and to an insulation resistance test to determine whether or not material deterioration has occured during the period of storage. The units should be inspected carefully to determine whether insulation has been damaged as a result of handling; whether any small parts (terminal, brush rigging, etc.) have been bent, broken, or lost; whether the generator has been damaged by weather, dirt, moisture, lubricating oil, or other harmful substance.

b. INSULATION TESTS. - The insulation resistance of a rotating machine should be checked when the unit is to be installed. Insulation resistance is the resistance to current leakage through and over the surface of insulation. This resistance can be measured without damaging the insulation and furnishes a highly useful guide for determining the general conditions of insulation. A 500-volt megger may be used to make this measurement. A megger test is performed before and after the machine has been run, while it is still hot. The resistance reading obtained should be compared with that listed in the manufacturer's instruction book.

A description of this megger test can be found in Chapter 4 (Test Equipment) of Navships 900, 171. Cold tests taken prior to placing a machine in service are especially valuable for determining whether the insulation is suitable after long periods of idleness, or after exposure to excessively humid or dirty conditions, or to water, shock, etc. Insulation tests should be taken after a machine has been repaired or serviced and on all new machines before being placed in service.

For preliminary measurements it is usually not essential to isolate the machine completely if isolation cannot easily be done. Disconnect as much of the connecting cable and associated equipment as is practicable by opening line switches, circuit breakers and contactors. Take care that no megger readings are taken across energized lines. The insulation resistance measurements taken in this manner will include the effect of the cable and equipment which is still connected. If the value of insulation resistance is lower than judged to be satisfactory, the machine must be further isolated by disconnecting the cables at the machine and repeating the tests. If the insulation resistance of the circuit within still measures too low, the internal connections should be disconnected and, proceeding progressively, measure the installation resistance of individual winding, coils, etc., until the low resistance portion is located. Shunt field circuits may be opened by disconnecting the leads connecting successive poles. Armature winding may be isolated by lifting all the brushes of the commutator. The test voltage should be applied between the copper conductor and a metallic part of the rotor rather than the stator, in order to eliminate the insulating effect of oil in the bearings.

Phase windings may be isolated from each other where terminals for both ends of each phase are provided. Brush-holder stud insulation may be measured separately when the brushes are lifted and the connections to the bus rings broken.

Breaking the circuit up into its components parts may not be necessary if the low insulation is suspected to be due to some general unsatisfactory overall conditions, such as the presence of excessive moisture in the insulation, condensation on its surfaces or accumulations of foreign matter. In such cases corrective steps should be taken and further tests made to determine whether the insulation resistance has been improved without breaking the internal connections within the machine.

It is impossible to set a rigidly fixed value for the minimum permissible insulation resistance on such equipment and state positively that if it has an insulation resistance below the minimum value, it will fail; or that if it has an insulation resistance above the minimum value, it will operate satisfactorily. Nevertheless, past experience has made it possible to set up limiting values of insulation resistance which serve to indicate the value that should be maintained.

Insulation resistance readings for "new" machinery when corrected to 77°F (25°C) (temperature of windings under test) should not be less than the following:

Motors and Generators (Direct Current)

Circuit	Insulation	Megohms
Armature	Class A	12
Armature	Class B	25
Field	Class A	25
Field	Class B	50

Generators (Alternating Current)

Circuit	Insulation	Megohms
Armature	Class A	25
Armature	Class B	50
Field	Class A	25
Field	Class B	50

Motors (Alternating Current)

Squirrel cage induction- (three phase)	25 megohms
All others	12 megohms

Shop-reconditioned machines will have insulation resistance readings much lower than those indicated for new machines, but in no case should readings on reconditioned machines be less than 1 megohm.

c. TEMPERATURE TESTS. – A temperature test may be run on the machine as an installation test, while it is in operation to determine if the bearings are overheating. When the machine is stopped, a small piece of plastic sealer (SNSN G17-1-5760) is applied to the outer race of the bearing; this acts as a holder for a thermometer having a range from 0° to 180°F. The mercury tip of the thermometer is inserted in the plastic sealer until the tip makes a firm contact with the bearings outer race. The machine is started and operated at full load until a maximum temperature is read on the thermometer. This reading is then compared with the reading listed in the manufacturer's instruction book or Navy Specifications.

d. TACHOMETER TEST. – The speed of rotation of a motor or generator may be determined by a tachometer test. Either a mechanical or electrical tachometer may be used. The shaft should be cleaned of all oil, grease or dirt before the test is made. The rubber-tipped probe of the tachometer is inserted in the center provided on the end of the shaft and the motor started. This test is made under load to determine the exact speed of rotation. The speed may be read directly from the scale on the tachometer. Care must always be used when handling a tachometer. They are delicate instruments and cannot stand rough treatment.

Standard Navy Stock Numbers of tachometers which may be used to measure the speed of rotation are as follows:

Range in RPM	SNSN
0-10,000	G40-T-21-400
300-10,000	G40-T-21-420

e. FINAL INSTALLATION CHECK-OFF. – Before starting any rotating electrical machine the following precautions should be observed.

(1) Check all mounting bolts. For large machines with foundations, the foundation bolts must be provided in accordance with drawings. The bolts must be tightened to guard against misalignment and vibration.

(2) Check bearings for alignment and lubrication.

(3) Check all rotating parts for freedom.

(4) Visually check the air gap between the rotor and stator for any foriegn or loose objects and for uniform spacing at all points.

(5) Check the field coils for proper connections.

(6) The commutator should be smooth and polished. When necessary, use fine sandpaper to polish the commutator, never use emery cloth. On new machinery, polishing should not be necessary, however.

(7) Check brushholders for rigidness and proper positions. Check brushes for proper fit to the curvature of the commutator or slip rings.

(8) Check the insulation resistance.

(9) Check the machine thoroughly for loose connections, obstructions in ventilating components and stray nuts, bolts or tools which may have been overlooked and left in positions where serious damage could result.

(10) Run at no-load (except series motors and similar types) and check for correct direction of rotation.

(11) Run at full-load and check speed and temperature rise.

SECTION 15-3

COMPONENTS INSTALLATION PROCEDURES

1. BRUSHES.

Brushes are an important link in the electrical circuit since they must form the connection to the rotor by way of the commutator or slip rings. If the brushes fit poorly or the brush pressure is too low, the contact resistance may be very high. If the brush pressure is too high, excessive wear and grooving of the commutator will result.

When the brush pressure is too high there will be sparking, excessive commutator wear, grooving, brush wear and brush crumbling. When the brush pressure is too low, there will be sparking, unsteady voltages, selective commutation and unbalance in the armature circuit.

In new installations some of the procedures to be observed are as follows:

a. GRINDING IN BRUSHES. – In the event that the brushes supplied do not fit the radius of the commutator or collector ring, the brushes must be "ground in". This is done by raising the brushes and placing a strip of sandpaper the approximate width of the commutator between the brush and commutator, rough side towards the brush. Apply spring tension to the brushes and turn the armature around in the direction of rotation by hand until a radius has been formed on the brush surface. After the brush has been shaped to almost fit the commutator, fine sandpaper should be used to obtain the final smooth fit, using the same process as described above.

About 70% of the brush area should be formed for good commutation. After the fitting of all brushes is completed, the dust and sand must be cleaned off care-

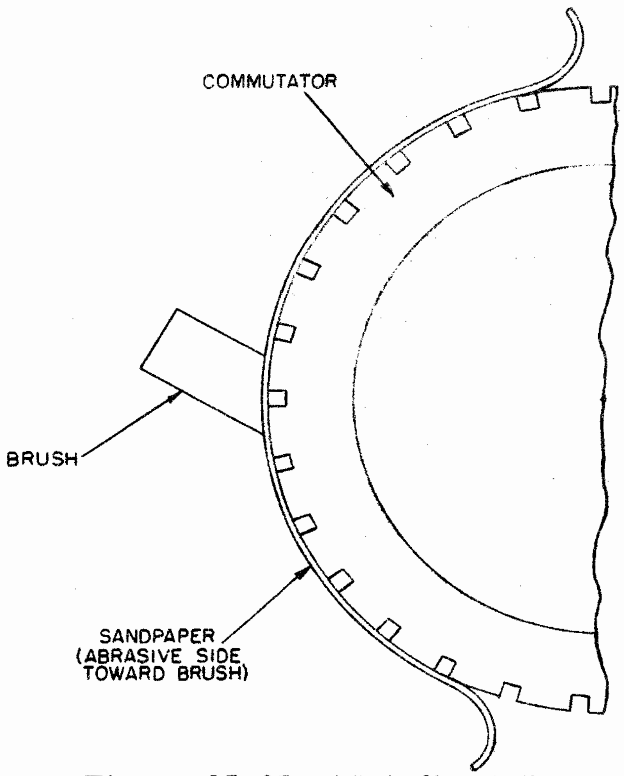


Figure 15-37. "Grinding In" the Brushes

ully and the brush pressure checked. (Figure 15-37.)

b. BRUSH PRESSURE. - The brush pressure should be correct for good commutation. The correct brush pressure in pounds per square inch can be found by multiplying 1.5 pounds times the surface area of the brush.

The pressure can be measured by using a brush tension gauge. Insert a strip of paper between the brush and the commutator or slip ring, using the gauge to exert a pull on the brush. Note the reading, in pounds, of the gauge when the pull is just sufficient to release the strip of paper so that it can be pulled out from between the commutator without offering resistance. This reading is divided by the contact area to give the brush pressure. The spring pressure should be adjusted for the correct pressure.

Brush Tension Gauge

SNSN	Capacity (Lbs.)
G40-G-2-500	0 - 15

c. BRUSH NEUTRAL POSITION.

The no-load neutral point on a commutator is the point at which minimum voltage is induced between adjacent commutator bars when the machine is running without load and with only the main pole field windings excited.

This is usually the best running position of the brushes on commutating pole machines.

The manufacturer usually dowels the brush studs in the proper position and marks the correct brush setting by a chisel mark or an arrow on a stationary part of the machine. In most cases, it is unnecessary to shift from the position marked by the manufacturer in new installations.

2. BEARINGS.

Ball bearings are used almost exclusively in Navy motors and generators, These bearings should never be exposed to dirt and dust except when it is absolutely necessary. Long periods of storage should be avoided because the bearings are subject to corrosion and to deterioration of the lubricant. The bearings should be stored in a place that can be kept reasonably clean and not subject to extremes of heat or moisture which would promote rusting or deterioration of bearing lubricants.

a. LUBRICATION OF BEARINGS. - The bearings of a motor generator should be inspected to make sure that they are free from dust, dirt and rust and that the armature turns easily. The bearings of these units are usually of the ball-bearing type and should require very little attention. They are usually equipped with sufficient grease in the bearings to provide six months or more of service after they are shipped and put into service.

When a motor or generator is put into service, check to be sure grease cups are filled halfway with grease. Do not screw down the grease cups unless the bearings actually require lubrication. Excessive grease is detrimental to ball bearings. A hot bearing may not be an indication of insufficient lubrication, but may be caused by excessive grease. Clicking bearings are an indication of insufficient lubrication or possibly a defective bearing.

Simple compression cups and grease drain plugs are specified for the bearing housing of grease-lubricated, ball-bearing type motors and generators installed on Navy ships. The pressure-gun method of applying grease should not be used unless the construction of the unit makes it impractical to use grease cups. In the event that grease must be added, it should be done as follows:

Use a grease meeting the requirements of BuShips Specification 14L3 or 14L7 (INT). Never use grease of doubtful quality or purity.

SNSN for Spec 14L3	Quantity
W14-L-84-900	1 lb can
W14-L-84-910	5 lb can

SNSN for Spec 14L7	Quantity
W14-L-189-814	1 lb can
W14-L-189-815	5 lb can

Wipe outside of grease cup and remove bearing drain plug and check for clear passage by probing with a clean screwdriver.

Remove the grease cup, empty it, clean it thoroughly, and pack it no more than one-half full of clean grease.

Empty and clean out the receptacle of the grease fitting down to the neck, then fill with clean grease.

Replace the grease cup and screw it down as far as it will go.

Run the machine and let grease run out of drain hole until drainage stops (normally about 30 minutes).

Replace the drain plug.

Repack the grease cup halfway with grease and screw down halfway.

b. BEARING HANDLING.– Even though most types of bearings look rugged, they must be handled as carefully as any piece of precision equipment should be handled.

Observing the following precautions will aid in proper installation.

(1) Do not remove the bearing from its container until every preparation has been made for installation. When the bearing is removed from the container make sure no foreign matter gets into it during installation.

(2) Be sure that the journal, housing, and all mating parts are of the proper dimension.

(3) Avoid damage during handling. Do not drop.

(4) Keep moisture away from the bearing.

(5) Use proper assembly tools.

(6) Use the correct lubricant in the prescribed amount.

c. MOUNTING A BEARING. – Never attempt to mount a bearing on a shaft that has not been wiped clean and given a light coat of oil. Dirt or chips on such a shaft would be trapped between bearing and shaft shoulder and prevent complete or accurate seating.

Never hammer on a bearing or apply full force until assured that the bearing is started straight and not misaligned. Forcing a cocked bearing distorts the inner race and may cause it to crack. Also the extremely hard race is likely to burr or score the shaft.

When the bearing is a tight fit on the shaft, as is usually the case, never apply mounting force to the bearing outer ring. This places a heavy thrust load on the balls and races before they are seated and in the case of bearings not meant for such thrust loads, it is likely to cause serious damage. An arbor press is the most satisfactory tool for mounting ball bearings. When properly used, no blows are struck and there is no danger of loosening shields.

Place the bearing on two flat blocks of equal size so that they contact the inner ring of the bearing. Then press shaft straight until the bearing is seated solidly against the shaft shoulder. Be sure that the blocks do not scrape or damage threads, if the shaft is threaded for a bearing locknut. The use of blocks that contact both rings is also good practice, provided the blocks are flat and the faces parallel. See Figure 15-38.

A bearing can be mounted on a shaft easily after it has been heated. A hot oil bath or an oven may be used to heat the bearing. When an oven is used, the bearing is heated with its wrapping still on. When bearing is hot, it is forced on the shaft and the locknut tightened.

A piece of heavy tubing may be used with a hammer to mount a bearing. A plug in the tubing and a shield outside help to prevent jarring dirt into the bearings. The hammer should be applied alternately at opposite points to avoid cocking and particular care should be taken when the bearing is started. (See Figure 15-39.)

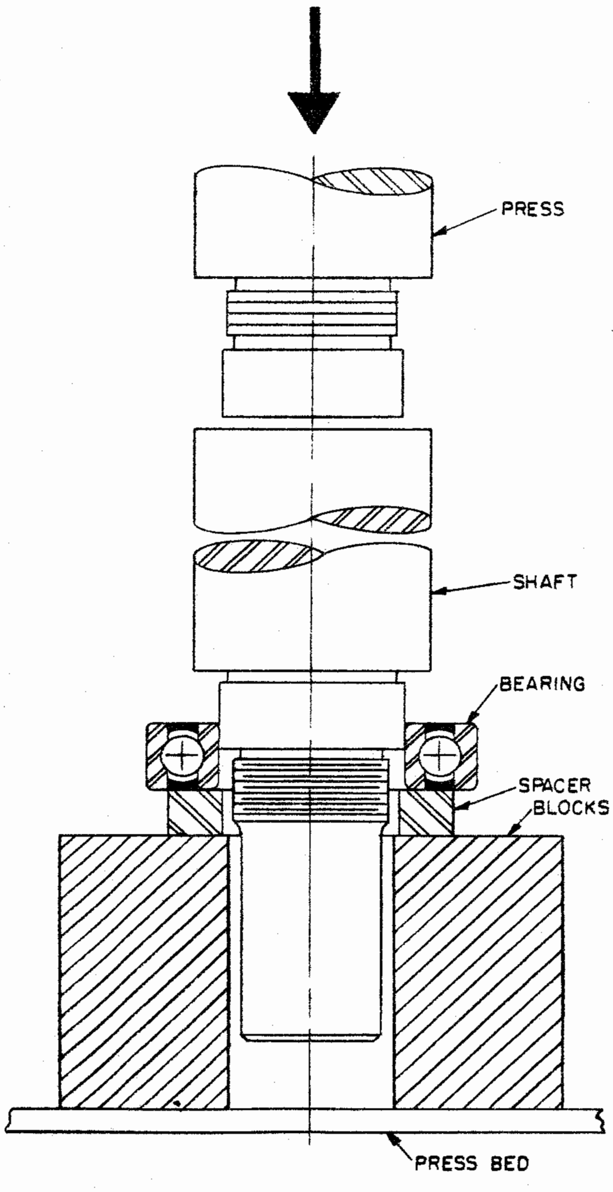


Figure 15-38. Arbor Press Method of Mounting a Bearing

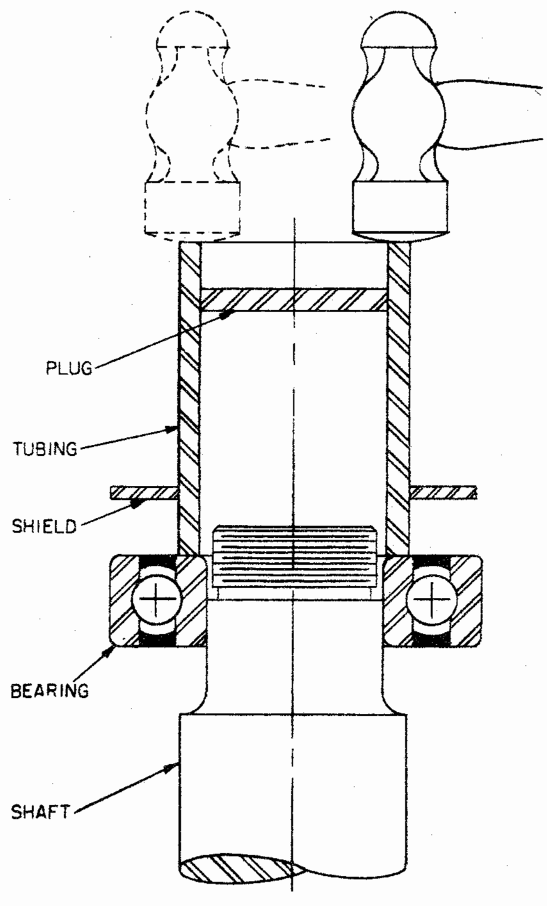


Figure 15-39. Hammer and Tube Method of Mounting a Bearing

The following precautions should be used when installing bearings:

(1) Be sure that the bearing and shaft are in perfect alignment to prevent scoring the shaft.

(2) If the bearing is a tight fit on the shaft, use pressure on the inner race only.

(3) If the outer race is a tight fit in the housing, use pressure on the outer race only.

(4) In no case force the bearing by hammering on it.

d. BEARING REMOVAL.- Ball bearings are nearly always a tight fit on the shaft and a push fit in the housing. Never hammer a bearing directly, especially on the outer ring. To do so will always cause some damage to the balls and races in addition to the possibility of fracturing the extremely hard race ring.

When a bearing is removed, it should never be spinned until it has been cleaned inside. When dismounted, a bearing is relatively loose and oil carries dirt between balls and races. If it is spun in this condition, the dirt can cause scratch marks which may later cause trouble.

An arbor press is one of the best demounting tools and should be used whenever it is adaptable. Rest the bearing inner ring or both rings (never the outer ring only) against a pair of flat blocks of the same size and using a firm, steady pressure, force the shaft out (Figure 15-40). Be careful to keep the shaft straight to avoid damage from cocking and don't let it strike the floor when it is suddenly released from the bearing. Also be careful not to drop the bearing, especially on a hard or dirty floor.

A claw-type puller which can be inserted behind the bearing inner race may also be used to remove a bearing. Be sure that the jaws are set so that they will not slip over the inner race and damage the separator or shield when pressure is applied. Exert an even pressure and pull straight. Cocking from unequalized pulling can damage both shaft and bearing. (Figure 15-41).

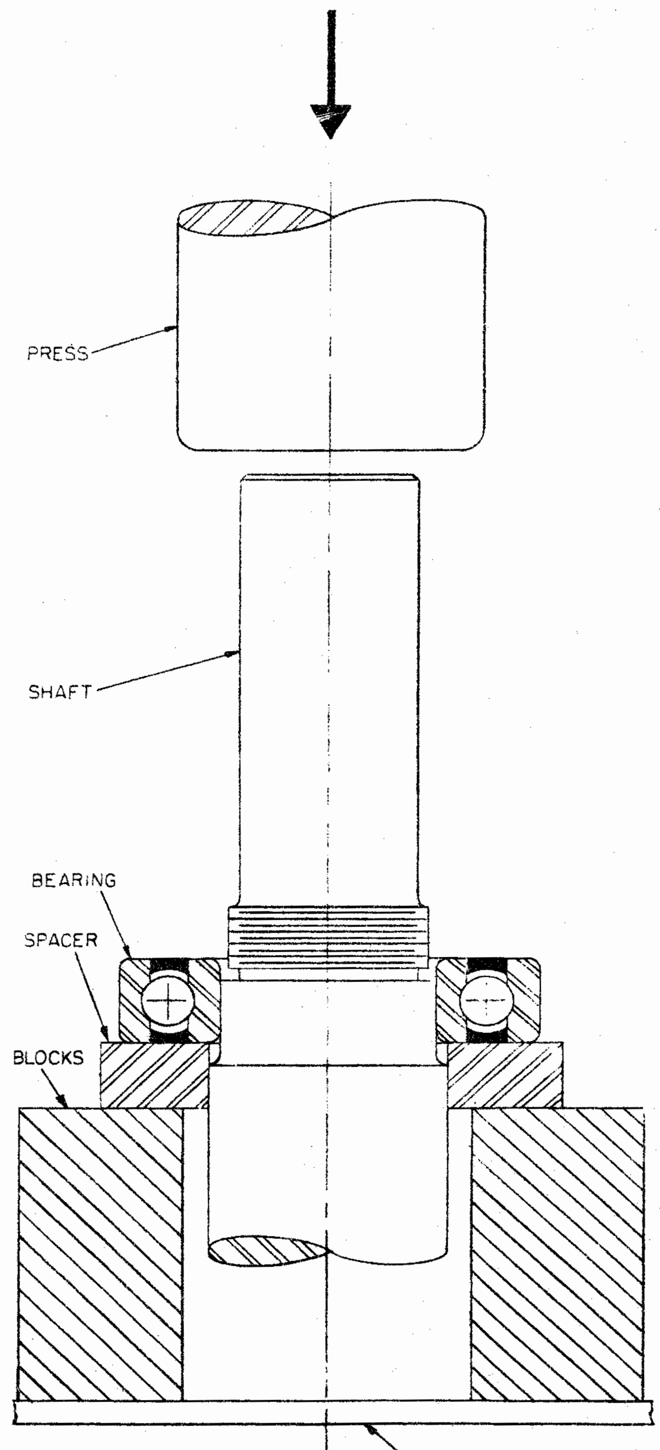


Figure 15-40. Arbor Press Method of Removing a Bearing

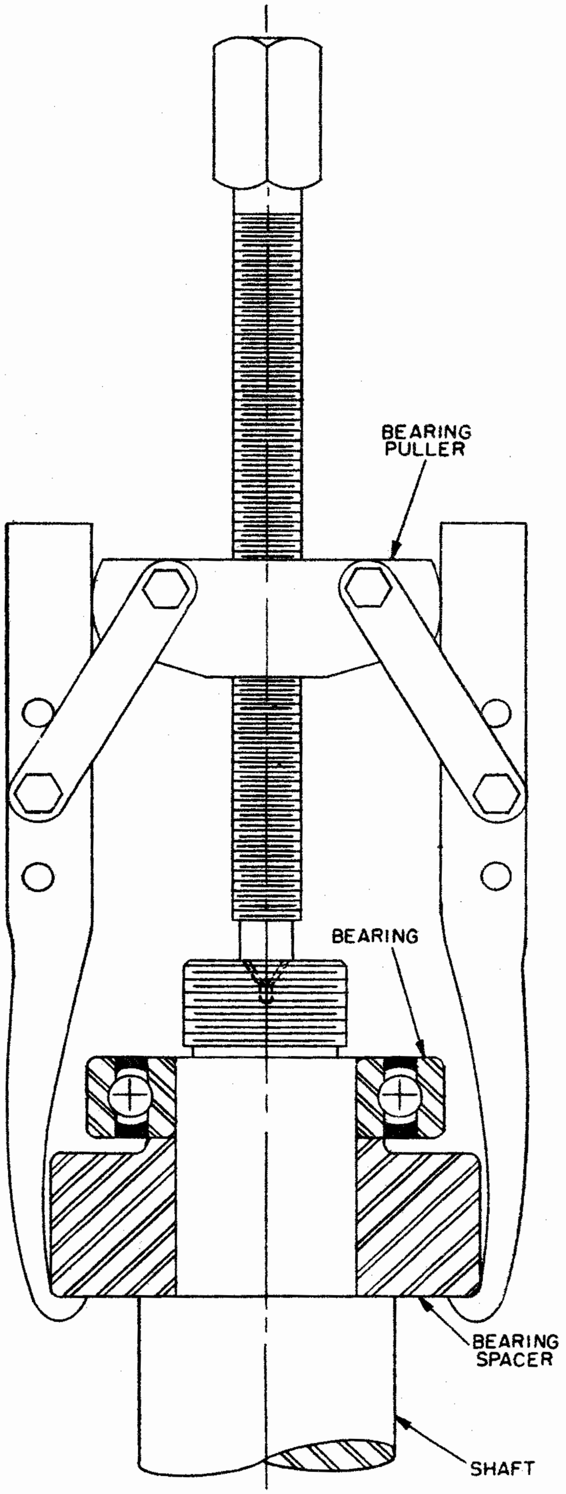


Figure 15-41. Removing a Bearing with Claw-Type Puller

In the case where gears or other removable parts do not allow the puller to contact the bearing, use the bolt-type puller on the parts. (Figure 15-42.)

The use of a hammer is to be avoided unless other methods cannot be employed. Split section of pipe or tubing with welded lugs (Figure 15-43) can be used for shafts of various sizes. Alternate blows on opposite sides will prevent serious cocking. Be sure that the pipe is free from chips or dirt that could fall into the bearing. When removing a bearing by pounding, care must be observed not to hit or, scrape the locknut threads on the shaft.

Cover bearings with a lint-free cloth or paper as soon as they are removed.

The following is a list of bearing pullers and their Standard Navy Stock Numbers which may be used to remove a bearing.

Claw-Type Pullers.

SNSN	Max Arm Spread (In.)
G41-P-2904-508	8
G41-P-2094-510	10
G41-P-2904-514	14

Pulling Attachments

SNSN	Capacity Range Diam (Inches)
G41-A-345-320	0 to 2-1/4
G41-A-345-325	0 to 5-3/4

Bolt-Type Pullers.

SNSN	Spread (Inches)
G41-P-2904-402	2 to 7-3/4
G41-P-2904-414	4 to 12-3/4

Comes with the following threaded legs

SNSN	Dimensions	
	OD	Length
G41-L-240-250	5/8"	6-3/4"
G41-L-240-252	5/8"	15-3/4"
G41-L-240-254	7/8"	4-1/2"
G41-L-240-256	7/8"	9-1/2"
G41-L-240-258	7/8"	16-1/2"
G41-L-240-260	7/8"	22-1/2"

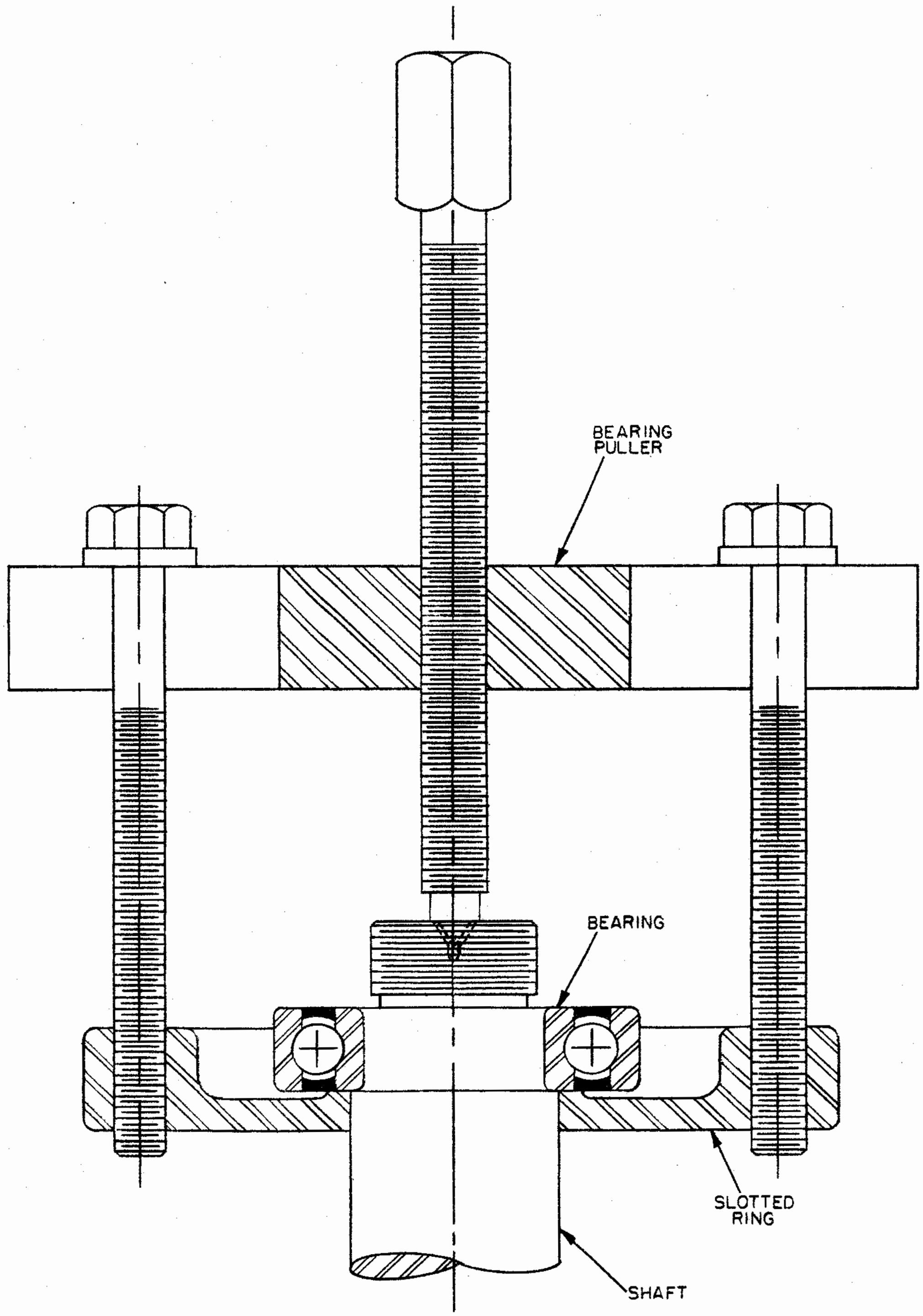


Figure 15-42, Removing a Bearing with Bolt-Type Puller

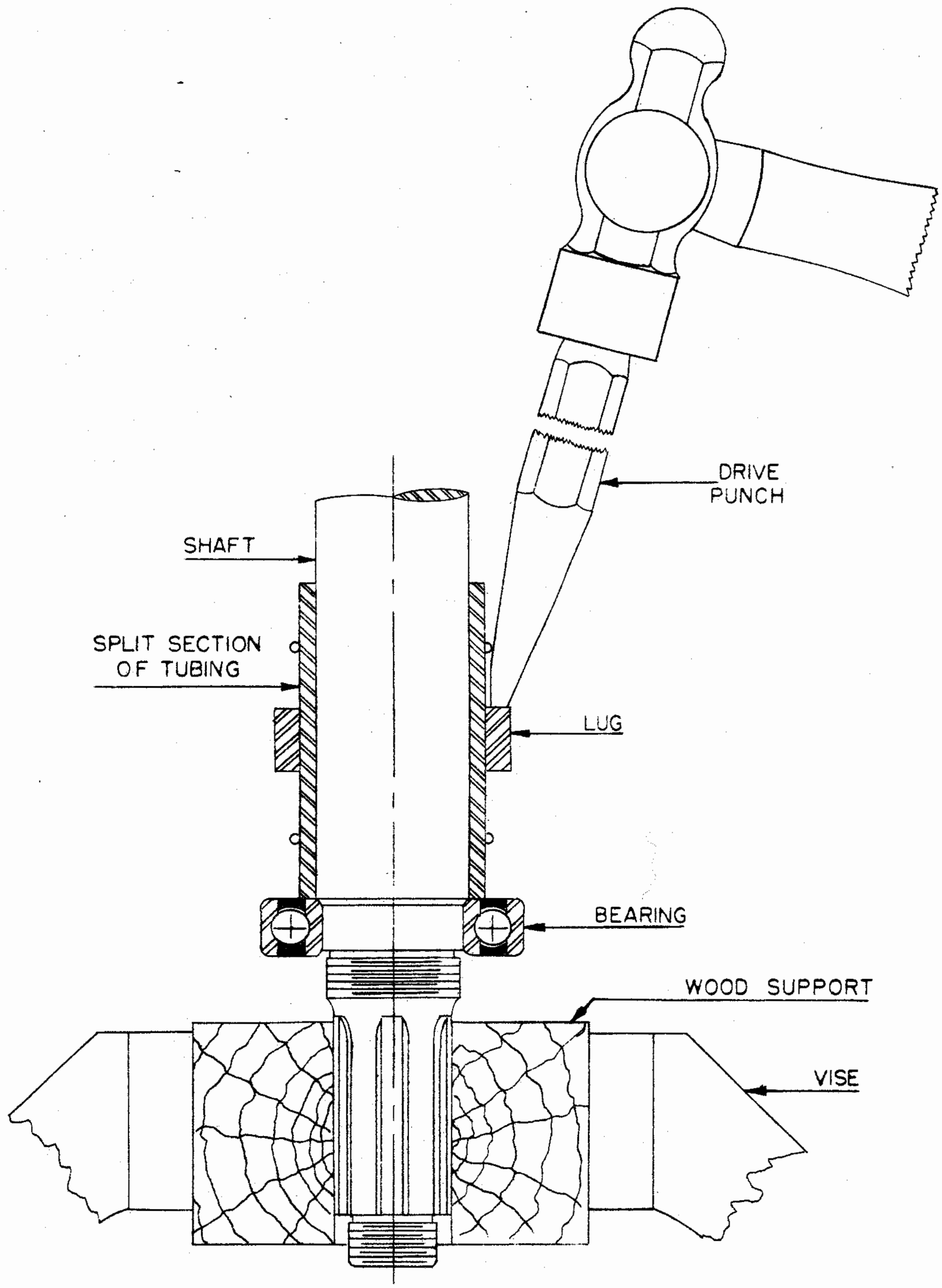


Figure 15-43. Removing a Bearing with Hammer and Tube

SECTION 15-4

TROUBLE SUMMARY

1. AC OR DC GENERATORS.

The following summarizes the most probable causes to be looked for when different types of trouble develop.

a. VIBRATION.

(1) When a generator vibrates under no-load, look for:

(a) Misalignment.
(b) Sprung shafting.
(c) Something chafing the rotor or armature.
(d) Loose coupling bolts, bearing, balance weights, or foundation bolts.

(2) When a generator vibrates under load, look for:

(a) Shorted field or armature coils.
(b) Unequal air gaps in either generator or exciter.

b. HOT BEARINGS.

(1) When the bearings on a generator run hot, look for:

(a) Misalignment.
(b) Unequal air gaps in either generator or exciter.
(c) Unbalanced rotor or sprung shaft.
(d) Insufficient oil supply.
(e) Sticking of oil rings.
(f) Clogging of oil lines.
(g) Dirt in lubricant or in bearings.
(h) Overgreasing (in ball bearings).
(i) Overload.
(j) Tight or poorly-fitted bearings.

(2) A generator with a hot bearing should be taken out of service as soon as the load can be shifted to other machines. Keep the generator turning slowly with no-load and supply plenty of clean oil until the bearing is cool. Do not shut it down immediately. An immediate stop may cause the bearing to freeze.

c. OIL LEAKS.– When oil or grease leaks appear, look for:

(1) Damaged or inadequate seals.
(2) Excess of oil or grease in bearing reservoir.
(3) Excess of oil flow in oil lines to bearing.
(4) Clogged return oil line from bearing.
(5) Clogged or closed vent.
(6) Use of vent as an oil hole.
(7) Suction of oil from bearing housing or vent by intake air to generator.

d. NOISY BRUSHES. – When brushes are noisy, look for:

(1) Too much clearance between collector ring or commutator and brush holder.
(2) Incorrect brush pressure.
(3) Rough collector ring or commutator due to:

(a) Flat spots.
(b) High mica.
(c) Loose bars.
(d) Pitting.
(e) Unbalance or eccentricity.

e. SCORING. – When collector rings or commutators show signs of scoring, look for:

(1) Hard particles embedded in the brushes.
(2) Check brush pressure.
(3) Check to make sure the proper grade of brush is being used.

f. BLACKENING OF COMMUTATORS AND COLLECTOR RINGS.

(1) BLACKENING OF A COMMUTATOR.

(a) On all bars; indicates incorrect brush pressure, brush position or poor adjustment of commutating field.
(b) On groups of bars at regular intervals; indicates the above conditions or poor brush contact.
(c) On a single bar this usually indicates an open armature coil.
(d) At irregular intervals it indicates roughness or eccentricity.

(2) BLACKENING OF COLLECTOR RINGS.

(a) An unbalanced condition of the rotor.
(b) Electrolysis.
(c) Action of acid fumes or salt on rings.

g. FAILURE TO GENERATE FULL VOLTAGE.

(1) When a separately - excited generator fails to generate at full voltage, look for an open circuit or ground in:

(a) The generator field rheostat.
(b) The leads in the circuit from the generator field terminals through the field rheostat to the excitation bus or exciter.
(c) The connection between the pole windings and from the pole windings to the field terminals in DC generators, or to the collector rings in rotating field AC generators.
(d) The connections between the generator field terminals and brushes in the rotating field AC generators.

(2) When a separately excited generator produces a substantial voltage but will not come up to normal rated value, one of the following causes may be responsible for failure to develop normal rated voltage:

(a) Speed may be below normal.
(b) Switchboard instrument may read incorrectly.
(c) Regulator may be set to regulate for too low a voltage.
(d) Part of either the field or stator windings may be short-circuited or improperly connected.

h. SELF - EXCITED GENERATOR FAILS TO GENERATE.

(1) A self-excited DC generator may fail to excite itself and build up voltage when started even though it operates perfectly during a preceding run, look for:

(a) Loose connection or break in the field circuits.
(b) Poor brush contact due to dirty commutator.
(c) Incorrect position of brushes.
(d) Open circuit or high resistance in the rheostat.
(e) Open or short circuit in the armature.
(f) Series and shunt field of compound wound generators connected to oppose each other.
(g) Loss of magnetism in field.

(2) If the machine fails to excite, interchange the leads from the positive and negative brushes.

(3) When a self - excited generator builds up voltage but not up to normal rated voltage.

(a) Speed may be below normal.
(b) Switchboard instrument may read incorrectly.
(c) Part of the shunt field may be short-circuited.
(d) Polarity of one or more field poles may be incorrect.
(e) Brushes may be incorrectly set.
(f) Part of the field rheostat or other unnecessary resistance may be in the field circuit.

i. ARCING BETWEEN BRUSH STUDS.

(1) May be caused by:

(a) Excessive voltage.
(b) Sudden excessive overloads.
(c) Rough or dirty commutator.
(d) Water dripping

j. OVERHEATING.

(1) Generator may overheat because of:

(a) Inadequate ventilation due to clogged air passages or ventilation ducts.
(b) Inadequate ventilation space.

(2) The field coils on generators may overheat because of:

(a) Low speed resulting in insufficient ventilation and cooling while requiring excessive field current to generate rated voltage.
(b) Too much current through the field coils.

(3) The stator of an AC generator of the armature of a DC generator may overheat because of:

(a) Overloading.
(b) A partial short of one or more coils.
(c) Short circuits or grounds on armature or commutator.
(d) Conduction of heat from hot commutator.
(e) Excessive inequalities in air gaps or rotor rubbing the stator.

(4) A commutator may overheat because of:

(a) Overloading.
(b) Sparking of brushes.
(c) Excessive brush pressure.

2. AC OR DC MOTORS.

The following are the probable causes of the more common motor troubles:

a. THREE-PHASE AND DC MOTORS.- Both three-phase induction motors and direct-current motors.

(1) Motor fails to start.

(a) Power not connected.
(b) Low voltage.
(c) Loose connections, broken connections or open circuit.
(d) Incorrect connections.
(e) Open or short circuit in motor windings.
(f) Grounded motor windings.
(g) Excessive friction.
(h) Stiff or frozen bearings.

(2) Motor stops after it has been running.

(a) Power supply fails.

(3) Vibration or excessive noise.

(a) Inadequate foundation or loose hold-down bolts on motor or driven machine.
(b) Loose electrical connections.
(c) Coupling misaligned or loose.
(d) Excessive belt tension.
(e) Air gaps not uniform.
(f) Rotor rubbing the stator.
(g) Objects caught between fan and end shield.
(h) Excessive load.
(i) Short-circuited coils.

(4) Bearings overheat (both ball and shield bearings).

(a) End shields loose or not properly replaced.
(b) Too much belt tension.
(c) Misaligned couplings or belts.
(d) Too much heat conducted to bearings from overheated windings.

(5) Sleeve bearings overheating.

(a) Not enough oil.
(b) Foreign material or dirt in oil.
(c) Oil rings rotate too slowly or not at all.
(d) Oil rings bent or jammed.
(e) Oil rings out of slot or retaining clip out of place.
(f) Bearing too tight.
(g) Defective bearing on scored shaft.

(6) Ball bearings overheat.

(a) Too much grease.
(b) Not enough grease.
(c) Dirt in grease.
(d) Bearings not aligned.
(e) Bearings damaged or corroded.

(7) Windings overheat.

(a) Heat conducted to winding from overheated bearing.
(b) Short-circuited coils.
(c) Overload.
(d) Incorrect connection.
(e) Rotor rubbing stator.
(f) Restricted ventilation.
(g) Low voltage on supply line.

b. THREE-PHASE INDUCTION MOTOR.

(1) Motor fails to start.

(a) Motor single phased. Frequently indicated by a humming noise.

(2) Noisy motor.

(a) Motor running single phase. Usually indicated by a humming noise.
(b) Current in three phase unbalanced.

(3) Motor overheats.

(a) Running single phase or with unbalanced currents in the three phases.
(b) Poor connections between rotor bars and short-circuited end rings.

c. DC MOTORS

(1) Motor runs too slow under load.
(a) Line voltage too low.
(b) Brushes set ahead of neutral.
(c) Overload.

(2) Motor runs too fast under load.
(a) Weak field.
(b) Line voltage too high.
(c) Brushes set back of neutral.

(3) Faulty commutation, high white spark under one brush. Grooving of commutator.

(a) Copper embedded in brush.

(4) Period sparking.

(a) Loose commutator with high bar.

3. AMPLIDYNES.

When an amplidynes is suspected of being defective it may be checked as follows:

a. There may be something wrong with the control amplifier or synchro system which does not allow it to apply proper signal voltage to the amplidyne control fields. This defect may be detected by checking error voltage to the control amplifier and the voltage applied to the amplidyne control fields.

b. The DC drive motor may not provide a constant load on the amplidyne. This problem can be solved by disconnecting the DC drive motor from the amplidyne armature and substituting a more constant load. Ordinary 120-volt light bulbs provide a convenient means of loading the amplidyne so as to check the voltage and current output. Since most shipboard amplidynes put out 230 to 250 volts at full load, you may connect two bulbs in series for a 250-volt load. Choose bulbs of the proper wattage so that the total wattage of the light bulbs equals the wattage rating of the amplidyne. The rated power output of the amplidyne may be found on the nameplate or in the instruction book.

In the event the amplidyne does not put out the required power, check the current drawn by the driving motor and measure the speed with a revolution counter or tachometer. Consult the instruction book for the full load current and revolutions per minute. Low motor speed and excessive motor current indicates either shorted motor stator winding or excessive friction due to misaligned end bells. These troubles usually cause the motor end of the amplidyne to overheat and will in time burn out the motor stator insulation.