Chapter 9640

Lighting

List of Effective Pages

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1 - 5	Original
6	Change 1
7	Change 2
8 - 12	Original
13	Change 1
14, 15	Original

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2V-SPBP-20AH storage battery cells. The lamp is rated at 6 volts but operated at 8 volts to increase light output. At full battery charge, the lamp produces more than 200,000 candlepower in the center of the beam. The lantern will run for about 3 hours on one charge. At the end of this time the light output is about half the full charge output.

9640.83. RELAY-OPERATED HAND LANTERNS

1. Dry battery powered, relay-operated hand lanterns are installed in certain strategic locations to prevent total darkness if the lighting power supply fails. These lanterns should not be installed in compartments having door switch control (article 9640.43), in magazines or powder handling spaces (except those spaces where only fixed or semi-fixed ammunition is handled), or in any locations where explosion-proof equipment is required. Lanterns should not be removed from the compartment where they are installed unless the compartment is to be abandoned entirely.

2. The relay for the lantern is connected to the power supply for lighting in the compartment where the lantern is installed. When power fails, the relay causes the lantern to light from its batteries. Two conditions must be satisfied in connecting the relay leads to the power circuit.

a. The leads must be connected to the power supply side of the lighting switch which controls lighting in the compartment. Otherwise, the lantern would light whenever lights are turned off.

b. The leads must be fused in such a way that a short circuit in the relay leads in one compartment will be cleared by low capacity fuses near the short circuit before heavier fuses closer to the source of power blow and cut off the lighting power supply to other compartments.

3. The lamp, Industry No. 1491, of the metal case lantern is rated at 2.4 volts, but is operated at 3 volts (when the dry batteries are new) to increase light output. Starting with fresh dry cells, the lantern will operate continuously for approximately 8 to 10 hours before the light output becomes too weak to be useful.

4. The lamp, Industry No. 4546, of the plastic case lantern is rated at 5.0 volts operated from two 6-volt, BA 200/U batteries in parallel with a peak voltage of 6.5 volts.

9640.84. FLASHLIGHTS

Flashlights are provided, one to a man. In an emergency, they can be used for short range Morse code signalling. One model of Navy flashlight is watertight. Another model is watertight and usually referred to as being also explosion-proof. It is not explosion-proof in the sense that the extension lights described in article 9640.36 are, but is, instead, intrinsically safe as described in article 60.184(5).

Part 2. Maintenance

9640.91. CHECK ON FLOOD LANTERNS, PORTABLE

1. **How to check charge.** The degree of charge of the storage batteries in portable flood lanterns (article 9460.82.) can be determined by observing the change indicator balls through the plastic windows in the battery case. When a cell is fully charged, all three indicator balls float at the surface of the electrolyte in the cell. As the cell discharges, the indicator balls sink in the following order:

a. The green ball sinks when approximately 10 percent of the cell capacity has been discharged.

b. The white ball sinks when the cell is 50 percent discharged.

c. The red ball sinks when the cell is 90 percent discharged.

2. **When and how to charge.** Batteries should be charged as soon as possible after the green ball sinks. Since a battery discharges at a slow rate even when not in use, a check should be made at least once each week to see if the green indicator balls are floating. If they are not, the battery should be charged. Direct current must be used for charging. If alternating current only is available, a suitable rectifier must be used. Cells should be charged at a rate of 1-1/2 to 2 amperes until all three indicator balls are floating. This will require from 20 to 25 hours if the battery is completely discharged. Charging should not be continued for more than an hour after the charging voltage has remained constant at 10 volts.

3. **Addition of water.** Pure water should be added, when necessary, to keep the electrolyte level at the indicator line marked on the front of the cell. DO NOT OVERFILL. Overfilling nullifies the nonspill feature of the battery and may cause electrolyte to spurt out through the vent tube. Furthermore, if the electrolyte level is not at the indicator line, the charge indicator balls will not correctly indicate the condition of charge in the battery.

9640.92. CHECK ON HAND LANTERNS

1. **Batteries.** The dry batteries in hand lanterns (article 9640.83) should be checked at least once every three months by operation of the hand lantern and observing the brightness of the lamp. When observed, if emitted light is dim, the batteries should be replaced immediately. Lanterns placed where the normal temperature is consistently higher than 90°F. should be checked more often. For example, the high temperature in boiler rooms may require that the battieries be replaced weekly in order to ensure adequate service from the lanterns.

2. **Relays.** In addition to the check of the batteries, the operation of the relay in lanterns should be checked at least once a quarter by de-energizing the lighting circuit to which the relay is connected. When the circuit is de-energized, the relay should operate and automatically turn on the lantern.

The circuit may be deenergized, on newer models, by pressure exerted on the push switch located on the relay housing.

9640.93 CHECK ON FLASHLIGHTS

Flashlights required for repair stations shall be checked every 6 weeks by operating the flashlight and observing the brightness of the lamp. If the lamp is dim, the batteries should be replaced.

SECTION VI - SHIPALT WORK INVOLVING CHANGES AFFECTING LIGHTING INSTALLATIONS.

9640.101. SPACE CHANGES

Where space changes, rearrangement, or functional changes are made as a part of shipalt work, the lighting installation will be modified, when required, to provide illumination meeting the requirements for the space involved. The planning activity should include, as a part of the shipalt involved, any incidental modifications to the lighting systems. Presently installed lighting fixtures should be utilized in accomplishing the new installation wherever possible. The level of illumination provided should be suitable for the new function of the space involved.

Chapter 9940 (Sec. I)

Salvage

List of Effective Pages

PAGE NUMBERS	CHANGE IN EFFECT
1 - 16	Original
17	Change 2
18	Original

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air to the charging hoses should be **opened.** The team captain will assign one of the team members the responsibility of operating the charging manifold valve.

5. When the ventilation and flooding procedures have been performed, the blow and vent valves should be secured, and each escapee checked. At this point, each escape will take a complete lungful of air, and the team captain will signal to open the air supply to the appliances.

6. As soon as the appliances are inflated the rapid pressurization of the trunk should be started with the air supply to the appliances kept open. It is important to remember that pressurization is started with a complete lungful of air and that continuous breathing is maintained during pressurization to avoid lung squeeze. This must be done even while each escapee attempts to equalize ear pressure.

c. **Ascent Procedure.**

1. When the escapees are ready to leave the trunk, the first man to leave should: (a) exhale completely, (b) take a deep breath and hold it, (c) shut the snorkel and remove it from his mouth, (d) unsnap the quick disconnect coupling, and (e) make his way through the escape door or hatch.

2. When the deck opening is reached, the escapee should exhale until he is comfortable, commence breathing normally, release himself, and continue to breath normally all the way to the surface.

3. Once he is underway to the surface, the escapee should put his hands above his head to guide himself to the surface and clasp his thumbs together to protect himself from collisions with overhead objects.

4. Immediately upon reaching the surface the escapee should start breathing through the snorkel, Then, if it is desired, the escapee can unzip the Steinke Hood and throw it back over his head.

d. **Life Raft.**

The escape appliances should not be worn while the life raft is being handled. They should be placed in the escape trunk away from the door before the life raft is placed in the escape trunk.

e. **Test and Inspection of Hooded Escape Appliance**

1. Quarterly, remove 25 percent of the hooded escape appliances (those with the earliest test dates) from stowage to a prepared test area.

2. Remove hooded escape appliances from stowage pouches. Inspect for mold and deterioration.

3. Check that whistle is attached to pocket with lanyard.

4. Check that tow cord with handle is in belt pocket and that pocket is attached to belt.

5. Check that snorkel valve operates freely between open and shut positions.

6. Ensure that snorkel mouthpiece clamp securely holds snorkel mouthpiece to snorkel.

7. Check that plastic viewing port is free of cracks and discolorotion.

8. Examine elastic collar and reinforced rubbing elastic for deterioration.

9. Check that hood zipper is fully closed by attempting to separate the hood from the life jacket section.

10. Inflate life jacket section with ship's air through the Schrader charging valve. When both relief valves lift at 1-1/2 to 2 psi, secure charging. (Both relief valves must operate properly.)

11. Leave inflated hooded escape appliance in test area for at least 12 hours.

12. If appliance deflates; reinflate it and place it in fresh water to detect leak(s).

13. Repair or replace damaged appliance.

14. Attached dated tag and restow each dry hooded escape appliance.

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Chapter 22

Steering Systems

List of Effective Pages

PAGE NUMBERS	CHANGE IN EFFECT
1 - 7	**Original**
9 – 15	Change 2

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22-38. INDICATING EQUIPMENT

Rudder and differential input (helm) mechanical indicators are provided in the steering gear room. The differential input shafting is driven by the control mechanism and indicates the rudder angle called for by the helmsman. The rudder angle indicator is linked to the rudder stock through the follow-up shaft and indicates the actual rudder position. Remote reading indicators are also provided at the distant steering stations and are covered in the *Bureau of Ships Technical Manual* Chapter 65, "Interior Communications Installations".

22-39. EMERGENCY STEERING GEAR

1. Emergency steering gear is provided on all combatant and auxiliary naval vessels having electro-hydraulic steering gear. Large combatant ships generally have electro-hydraulic emergency steering gear. On other ships the emergency gear usually consists of a hand-operated hydraulic pump supplemented by chain falls or jacking nuts.

a. Hand driven emergency steering. Hand powered emergency steering gear consists of a hydraulic gear pump, which will operate in either direction of rotation, and associated shuttle valves, piping, relief valves, and fittings. This equipment is installed in the steering gear compartment with the pipes from the hand pump connected to the ram drain lines to eliminate the need for additional high pressure cut off valves. Automatic, or in some cases manual, positioning of the transfer valves on lock position, isolates the rams from the main pumps to prevent motoring of the main power units. The hand pump is generally the same pump used to fill and drain the hydraulic system. A few classes of ships have an emergency hand steering system where the electric motor is declutched from one of the main pumps and the pump is hand cranked. The pump is usually set at a reduced stroke for hand steering. The emergency steering systems described here require an intact hydraulic system for operation, therefore, rudder positioning equipment is also furnished in the event the hydraulic system becomes inoperable. This equipment generally consists of jacking nuts, drum and cables, or in some older installations, chain hoists. Rudder positioning equipment should only be employed when the vessel is dead in the water.

b. Electro-hydraulic emergency steering gear. Many large combatant ships have a separate hydraulic power unit for each steering gear, located in the opposite steering gear room or in a separate compartment above the water line. These units consist of electric motors driving variable delivery pumps which are usually connected to two cylinders of the ram group. These systems can operate with the ram cylinders and main steering gear submerged. All connections and valve operation is done automatically. A hand wheel controls the flow of oil to the rams and operates the rudder at a greatly reduced rate. Hand steering or rudder positioning systems are seldom furnished on the largest classes of ships as the effort required to overcome friction and normal hydraulic leakage alone is greater than that which can be applied by four men turning a gear pump.

c. Submersible emergency steering gear.

(1) Some large combatant ships are equipped with emergency submersible steering systems. These systems employ a hydraulic pump which can be either hand driven through shafting connected to a cranking unit located above the waterline or driven by a submersible electric motor with control pushbuttons located at an operating station above the waterline. The hydraulic pump functions automatically to connect itself to one pair of ram cylinders. At the same time it disconnects the main steering pumps from these cylinders and provides a by-pass circuit for the ram cylinders not in use. This automatic "shift-over" is accomplished by the first few revolutions of the emergency pump. Nonoverhauling and anti-kick-back protection are built into the emergency unit and replenishment of oil is automatically accomplished.

(2) The submersible electric motors used in this emergency gear are rated for continuous duty submerged. For operation in air the motors are rated for a 30 minute duty cycle and a maximum of six starts per minute at one-third load rating. The motor control is so arranged that the "master" button must be held in and the "right" or "left" button depressed to move the rudder.

(3) Changing back to the main steering system after using the emergency submersible gear requires a manual reset of the "shift-over" valve located on the unit assembly.

22-40. HYDRAULIC PUMP SERVO SYSTEMS

The force required to operate the tilting block in large variable delivery hydraulic pumps is considerably greater than the relatively low torque control systems can apply. To make the tilting block operable by the control mechanism a hydraulic servo-system is provided on the pump. The servo is essentially a control valve which regulates a flow of oil from a servo pump (servo pressures range from 100 to 800 p.s.i.) to a pair of servo pistons which move, or hold in position, the tilting block. The servo pump may be separately driven by an electric motor, however, most recent installations have the servo pump driven from the main pump shaft. The servo pump may also be sufficiently oversized to provide replenishment oil for the system. The oil pressure is generally reduced to approximately 30 to 60 p.s.i. for replenishing. The servo-system has its own follow-up system built into it whereby the tilting block stops at the stroke called for by the control differential mechanism.

22-41. MECHANICAL CONTROL DIFFERENTIALS

Mechanical differentials will be discussed here although the mechanisms are considered a part of the steering control system which will be discussed in Section IV. Some type of mechanical differential is used with steam steering gear, however, the major application is on electro-hydraulic steering gear.

a. A mechanical differential is a vital part of the steering gear. Its function is to provide positioning control whereby a rudder angle is ordered by the distant control mechanism or the steering room hand (trick) wheel and the power unit is activated to bring the rudder in the required direction and to stop the action when the rudder reaches the assigned angle. Failure of a differential mechanism results in loss of steering control by the power unit controlled by that differential. On those installations where a single differential controls both power units of a dual system, all power steering control will be lost if the differential fails. For this reason maintenance of the differential, as outlined in section 22-43 and in applicable instruction manuals, should be carefully followed.

b. The most widely used mechanical differential is the rotary cam type. This mechanism consists of a system of gears, barrel cam, and cam follower. Rotary motion from the remote control system, or the trick wheel, is transferred through shafting and gears to the input side of the differential. By means of the differential gears this rotary displacement is transferred to the barrel cam so it turns a proportional amount. The face, or outer circumference, of this barrel cam has a groove which is cut so that a follower, riding in this groove, displaces from the center of the cam face as the cam rotates. The path of the groove is such that rotation of the cam in one direction forces the follower to one side of the cam face (the follower can move only in a linear direction parallel to the cam axis) and rotation of the cam in the other direction forces the follower to the other side of the cam face. The cam follower is connected to the hydraulic pump stroke control by mechanical linkage. The angle at which the groove displaces from the center of the cam face, and the distance it displaces, are such that full stroke of the hydraulic pump is obtained by rotation of the barrel cam through an arc representing 7 degrees of rudder angle. After reaching these full stroke displacements, to either side of the centerline of the cam face, the grooves are continued around nearly the entire periphery of the cam, parallel to the centerline. The differential gearing and input to the differential are so arranged that the maximum rotational displacement of the neutral position on the cam face from the cam follower is somewhat less than 360 degrees. Linkage and gears (called follow-up gears and shafting) attached to the rudder stock, transmit the motion of the rudder to the differential gears opposite those driven by the control unit. These follow-up gears or shafts are connected so that as the rudder moves in the direction called for by the control (effected by the differential, barrel cam, follower and hydraulic pump) the follow-up gears tend to rotate the cam in the opposite direction from that which the cam was turned by the control unit. As the rudder turns the cam turns until the follower is brought to the place in the cam groove where the stroke control is reduced to zero. When this zero stroke position is reached the rudder stops and the rudder angle indicator will then coincide with the helm angle indicator. As stated in article 22-56, the horsepower limiter device may reduce the stroke of the pump, as called for by the differential cam, in order to reduce the power requirement. This reducing of the pump stroke has no effect on the action of the differential except to reduce the rudder rate. A few classes of ships use a simple system of levers actuating linear type control valves to provide follow-up and storage motion. These systems are generally used only on small ships.

22-42. ADJUSTABLE CONTROL STOPS

Adjustable control stops are provided in the control system to limit the movement of the differential input shaft to the equivalent of hardover to hardover rudder movement. It is important that these stops be correctly adjusted to prevent damage to the differential gears and follower mechanism in case the follower reaches the end of the groove in the cam face. The stops also protect other components of the steering system. To further safeguard the steering gear against damage, in case of improper control stop adjustment or mechanical failure, the rams are arranged to bring up against renewable copper crushing pieces before the rudder reaches the extreme limits of its travel. The settings of the copper crushing pieces on the tie rods between the ram slippers and the steel positive stops are to be checked to assure equal bearing on all stops. These checks should be conducted by experienced shipyard personnel only.

22-43. MAINTENANCE OF ELECTRO-HYDRAULIC STEERING GEAR

Complete maintenance of all types of electro-hydraulic steering gears would be far too voluminous to include here. Instruction books furnished with each particular installation should be referred to for complete maintenance instructions. A few items requiring special attention will be discussed here because of their extreme importance to safety and protection of the steering gear and because they are applicable to nearly all hydraulic steering gear.

a. Cleanliness of hydraulic systems. The importance of cleanliness in hydraulic systems cannot be over emphasized. Dirt or foreign matter in steering systems can destroy hydraulic pumps, cause valves to stick, score cylinders, ruin packings, and disrupt control systems quickly and with possible disastrous results. Systems should never be opened except for good cause and then only by experienced, qualified personnel. Care should be exercised to keep out dirt while systems are open and all parts should be carefully cleaned before being reinstalled in the equipment. Any filters installed in the active hydraulic system should be changed or cleaned regularly. All the oil in the active system should be pumped through the installed external filter at least once each 6 months and any oil added for replenishment of the system should be carefully filtered. Only approved gasket materials or packings should be used when replacing such materials in the steering systems. Any pipes or tubing which are detached from the system during repairs should be plugged and protected from damage while removed. Only clean hydraulic oil of the type specified for the system should be used for refilling or replenishment. Extreme care should be exercised to keep any water from entering a hydraulic system.

b. Ram packings. The packings used in the ram cylinders are designed so the edges are expanded against the ram by the pressure of the oil in the cylinder. It is important that the packings be of the specified type and that they be correctly installed. The packing glands should be drawn up just tight enough to allow a film of oil to remain on the rams as they emerge from the cylinders. An occasional drop of oil leaking past the packing is not considered objectionable. Packing glands which are drawn up too tightly cause excessive ram wear, have excessive friction, permit dirt, which falls onto the rams, to be forced into the packings (a film of oil on the ram tends to wash away the dirt) and wears out the packing prematurely.

c. Control differential maintenance. Differential mechanisms should be adequately, but not overly, lubricated with clean, specified lubricant. Repairs and internal inspections should only be carried out by competent authorized personnel. Inspection of the differential should be accomplished at each scheduled overhaul. The differential and the mechanism in the differential control case should be flushed with a cleaning fluid, inspected for damaged or worn parts, and adequately lubricated. If parts are removed or disconnected care must be exercised to realign all shafts, gears and couplings in their correct position before reinstalling. Some early designs of differential controls had clutches installed in the follow-up shafting and trick wheel shafting. Except for the clutch at the trick wheel (to disengage it from the distant remote control) all such clutches should be rendered inoperative or replaced with a coupling.

SECTION IV. DISTANT CONTROL SYSTEMS

Part I. Electrical

22-51. GENERAL DESCRIPTION

Electrical distant control systems for steering gear are divided into 2 general types, the electric servo type and the synchronous transmission type. The design of steering control systems, while primarily dictated by the operational requirements of the various type ships, is also influenced by characteristics of the steering gear machinery. Modern steering gear is designed for faster rudder rates and larger hard-over angles than former steering gear. Recent designs of hydraulic pumps have built-in servo control valves which require only inch-pounds of control torque as compared to foot-pounds of torque required when pumps were stroked directly or by separate servo valve arrangements. This has made possible smaller and more responsive control systems.

22-52. SYNCHRONOUS TRANSMISSION CONTROL SYSTEMS

1. *Power type.* The power type synchronous transmission system is also identified by such trade names as "synchrotie" or "power-selsyn". These systems consist of interchangeable receiving and transmitting units which are, in reality, wound rotor induction motors with interconnected three-phase rotor windings. The stator windings are connected to the same A.C. power supply. When the transmitter rotor is turned, the receiver rotor turns in synchronism, i.e., at the same speed and in the same direction. The transmitters are located in a steering stand, or console, in the pilot house and in some cases in the secondary conning station. The transmitters are mechanically connected through gearing to the steering wheels. The transmitter at each of the distant control stations is electrically connected to the receiver, or receivers, in the steering room, or rooms. Where there are multiple steering stations a switch is provided for selecting the desired control station. Generally, the circuits connecting the transmitters to the receivers are run in duplicate cables, one running along the port side of the ship and the other along the starboard side. Indicator lights are provided on the steering stands and at the selector switch station to indicate the cable, transmitter, receiver, and power source in use. Overload protection for the systems is provided. Current approximately 500 percent greater than the normal requirement is transmitted through the circuits when transmitters and receivers are pulled out of synchronism. While pulling the units out of step (synchronism) is rarely done in normal operation, and should never be done intentionally, it is possible to do so when the receiver is hard against the stops and the helm is turned farther than the hard-over position. The high current resulting from this condition will cause the over-load relays to trip if the units are held at the point of maximum pull-out torque for any length of time or if thrown out of step repeatedly. In order to prevent loss of steering control due to over-load relays cutting out, and to prevent possible damage to the system, the following procedure is recommended when using hard rudder:

a. Move the wheel as rapidly as desired until the helm angle indicator pointer approaches 3 degrees from the hard over position and then ease it to the hard over angle.

b. Do not force or hold the wheel beyond the hard over position.

2. *Synchro type.* This type synchronous transmission system is also known as "torque type synchro control" This system is the latest control system developed for naval ships. It is identical to the power selsyn or synchro-tie system except that the transmitter and receiver units are much smaller, and less costly, in this system. The size 7 synchros, generally used in this system, have sufficient torque to handle all steering gear control mechanisms since built-in servo valves in the hydraulic pumps and light-weight differentials required to stroke these pumps have been developed. Being lighter and smaller these units are somewhat more susceptible to pull out. In normal operation pull out has been virtually eliminated by careful calculation of damping, gear ratios, differential inertias, using low inertia synchro rotors and keeping the voltage drop in inter-connecting cables to the lowest practicable value. Navy standard synchros, with required gearing and cables, are the only components required for the synchro control system. Because of its simplicity, low cost and effortless steering, this system is the most widely used in new construction ships. It is important that the hardover rudder procedure as described in the preceding paragraph, under power type synchronous transmission control systems, be followed with the synchro type system also.

22-53. HAND ELECTRIC SERVO SYSTEM

In order to meet specific steering requirements on various vessels and before the torque-synchro system was developed, an electric, closed loop, servo system was developed. This system was installed on the MSO 421 class vessels and on various combatant and auxiliary vessels starting with the DL-1. The system consists of a synchro, or in some cases a potentiometer, geared to the steering wheel and connected through cables to a synchro or potentiometer, in the steering engine room. A voltage, proportional to the angular displacement of the transmitter with respect to the receiver, is generated and used as an input signal to a magnetic amplifier. The output from the amplifier controls a servo motor which in turn operates the hydraulic pump servo valve. Variations of this type control are used in the automatic steering devices discussed in section V.

22-54. MAINTENANCE OF ELECTRICAL CONTROL SYSTEMS

1. Any apparent deficiencies in the electrical steering control system such as sluggishness in operation, improper setting of rudder limit stops, or misalignment should be investigated and reported immediately. If the repairs required are beyond the capacity of the ships force a work request should be submitted for correction of the deficiency as soon as possible. Experience has shown that after ships have been in service for some time, there may be a variation in helm and rudder indication. This variation is usually caused by wear or damage of parts. In most cases a variation of 1 or 2 degrees does not warrant a complete overhaul of the complete control system. Many times most of the error can be eliminated by taking up lost motion in linkages and gear trains. When making adjustments or repairs to the indicating equipment the graduations on the ram group or on the rudder stock should be used as a reference.

2. Excessive steering wheel effort in power selsyn or synchro-tie systems can be caused by: (1) insufficient lubrication of gears and bearings in the steering stand, (2) insufficient lubrication of pins and bushings in the pump control linkage, (3) insufficient lubricant in the mechanical differential, (4) misalignment of control linkages or (5) misalignment of coupling between receiver and differential.

3. All electrical cables should be inspected thoroughly in accordance with Chapter 60-261. Inspect all electrical connections and circuit breakers (particularly terminals and terminal board connections) at least once a year and during each overhaul.

Part II. Hydraulic Telemotors

22-55. HYDRAULIC TELEMOTORS FUNCTIONS

A telemotor is a hydraulic device by means of which the steering gear of the ship or submarine is controlled from the pilot house or control station. Generally, telemotors are employed in conjunction with electrical steering control systems on replenishing type ships.

22-56. GENERAL DESCRIPTION

The hydraulic telemotor system consists of one or more transmitters located at a distant steering station, or stations, connected by piping to a receiver or receivers located in the steering engine room. Each transmitter and receiver unit is so arranged that movement of the steering wheel forces oil through the system resulting in movement of the plungers in the receiver unit. The receiver plungers are connected to the pump control or valve operating mechanism of the steering engine. Transmitter units are of two general types, plunger types and rotary pump types.

a. Plunger type telemotor transmitters. Old designs of telemotor transmitters employ two plungers which are driven by a pinion and racks from the wheel. This type requires that the wheel be brought to the amidship position to replenish the oil in the plungers. With this type transmitter, centering springs are provided on the receiver units to assist in keeping the system aligned. The force of the springs must be overcome each time a movement of the telemotor away from the amidship position is required. In prolonged turns, with a system which has any appreciable leakage of oil, it is possible to reach the limit of the transmitter plunger stroke. This would then require going to the amidship position to replenish the plunger before full steering control could be obtained. Under certain conditions bringing the rudder amidship may be impossible or dangerous.

b. *Rotary pump telemotor transmitters.* New designs of telemotors employ a reversible, parallel piston, rotary pump, to deliver oil to the receiver. In this system the transmitter can continue to be turned until the receiver reaches the end of its stroke regardless of leakage. At the end of the stroke the oil pressure builds up until a relief valve opens and the oil is discharged to a built-in supply tank. Replenishing oil, to make up for leakage, is automatically drawn from this supply tank as required and at any helm angle. No centering springs are installed on the receiver units of this system, therefore no wheel effort is required to hold a given rudder angle. Synchro type indicators are used with this system to relay to the helmsman the angle called for at the telemotor receiver. The indicator transmitter is gear driven from the telemotor receiver plunger and the indicator receiver unit is mounted in the steering console.

22-57. FILLING TELEMOTOR SYSTEMS

Specific filling and purging instructions for the telemotor systems should be obtained from applicable steering gear or telemotor manuals as these instructions vary depending upon the type of unit and the specific installation. Care should be exercised however to insure that the replenishing tank for all types of systems be kept at least three-quarters full of oil at all times.

22-58. TELEMOTOR OIL CHARACTERISTICS

Telemotor hydraulic systems should be filled with 51F-21 ordnance oil. Recent tests have indicated this oil is most satisfactory for both high and low ambient temperatures. If 51F-21 oil should be unavailable it is satisfactory to use Navy standard hydraulic oil, symbol 2075H. Old telemotor installations may specify a mixture of glycerin and water for the operating fluid. This mixture should not be used under any condition and any system which may still use such a mixture should be thoroughly cleaned and refilled with oil as specified above. Oil should be strained through four to six layers of cheese cloth when entering the charging tank. This serves to demulsify the oil as well as strain out any foreign matter. Care should be exercised to keep all water or condensation from contaminating the oil.

22-59. MAINTENANCE OF HYDRAULIC TELEMOTORS

Excessive steering wheel effort can be caused by lack of lubrication of the transmitter gears and bearings, binding linkages on the steering engine, a restriction in the hydraulic lines, packings drawn up too tightly or improper oil in the system. In addition to insuring that only clean oil is used in the system, it is extremely important that all parts be kept clean when the system is opened for repair or inspection. Normally there is little wear of internal parts of a telemotor system and it will seldom be necessary to dismantle the units. Packings should be drawn up only sufficiently tight to prevent excessive leakage. A film of oil left on the plungers is desirable to prevent scoring the plunger and for ease of operation.

SECTION V. AUTOMATIC STEERING DEVICES - SURFACE SHIPS

22-61. GENERAL DESCRIPTION

Automatic steering equipment is installed on certain auxiliary vessels. Such systems are suitable for installation only on ships having a gyro-compass. Automatic steering devices are designed to keep a ship on a given gyro compass course automatically. All such systems have provisions for use as straight hand electric systems if desired.

22-62. MAINTENANCE OF AUTOMATIC STEERING SYSTEMS

The various manufacturers of automatic steering gear control systems issue operating and maintenance manuals which are provided with the equipment. When the repairs or adjustments required on the automatic steering system are beyond the capacity of naval repair activities the services of the manufacturers field engineers should be requested.

SECTION VI. STEERING EQUIPMENT FOR SUBMARINES

22-71. GENERAL DESCRIPTION

In general, the steering equipment for submarines conforms with that of surface ships described herein, except that electro-hydraulic gear is used on all ships. On the older ships, a centering spring is attached to the tilt block control shaft of the hydraulic pump, which returns the tilt block to neutral after the helmsman has returned the steering wheel of the telemotor pump to neutral. This is known as the Waterbury pump rate-type control system. On the newer submarines, the positioning of the rudder is directly proportional to the helm wheel movement, through a synchro transmission position control servo system. This is known as the position-type control system.

22-72. METHODS OF STEERING

Three methods of steering are used on submarines, i.e., normal power, emergency power, and hand steering. In normal power steering, an electrically-operated hydraulic pump delivers hydraulic fluid to the steering rams. On older ships this power plant is separate, and is located in the aft end of the ship. On recent construction the steering gear rams receive their power from a hydraulic pump(s) which is centrally located on the ship. In emergency power steering, the source of power is the main hydraulic system on the older ships, and the vital hydraulic system on recent construction. For hand steering on older submarines, separate leads of piping are taken to the steering gear rams from a manually operated hydraulic pump in the control room. The same arrangement is used on recent construction, for hand steering, except that the hand pump is located at the aft end of the ship, near the rams. Direction of rudder movement, by hand, is controlled, on submarines with the hand pumps in the control room, by a valve provided near the pump. The same valve is used, in emergency operation, to direct the flow of hydraulic fluid from the emergency system, i.e., main or vital. On some ships, an additional control method, known as jury rig control, is provided in case of failure of remote rudder indicators in the control room. Jury rig operation is accomplished in the stern room, within sight of local indicators.

22-73. AUTOMATIC STEERING ON SUBMARINES

Automatic steering equipment provided on older submarines such as an automatic pilot, (Iron Mike), has not been provided on recent construction. Instead, an automatic course keeping control (CKC) system has been installed on the newer submarines with emphasis placed on accurately holding course under varying conditions of speed and weather for both surface and submerged operation. This mode of steering utilizes a closed loop servo system consisting of synchros, magnetic amplifiers, servo motors, servovalves and the submarine itself as the return loop. An automatic course control (ACC) system capable of making course changes, in addition to keeping course, will be installed on new construction submarines.

22-74. OPERATION OF CKC AUTOMATIC STEERING SYSTEM

In the CKC mode of operation, when a submarine tends to deviate from an ordered course due to uncontrollable outside forces, the relative position of the compass, and the heading changes. This induces an error signal voltage in the synchros associated with the compass and heading. This signal voltage, being quite small, is amplified by magnetic amplifiers. The amplified signal energizes a motor which operates a proportional servovalve which in turn ports hydraulic fluid to the rudder rams, positioning the rudder in the proper direction so as to return the ship to the ordered course. The rotating rudder activates a synchro, producing a voltage in a direction to reduce the error signal voltage to zero which returns the servovalve to its closed position and the rudder remains at the angle required to correct the ship's deviation. As the submarine returns to its original heading, the above procedure is repeated until the rudder returns to its amidships position and the submarine is again on course.

22-75. OPERATION OF ACC CONTROL SYSTEM

The automatic course control (ACC) system can make course changes automatically in the same manner as shown above except that the heading indicator is manually changed giving rise to the error signal.

SECTION VII. DIVING EQUIPMENT FOR SUBMARINES

22-81. GENERAL DESCRIPTION

Automatic diving equipment is installed on most of the recent construction submarines in the form of an automatic depth keeping control (DKC) system and on some newer submarines as a combination DKC and automatic depth control (ADC) system having depth changing capabilities.

22-82. OPERATION OF DEPTH KEEPING CONTROL (DKC)

The automatic depth keeping control (DKC) system is similar, both component-wise and in operation, to the CKC system (see Section VI, paragraphs 22-84 and 22-85) except that the error signal is the difference between the ship's depth sensor or depth detector and ordered depth. The feedback (or follow-up) signal is generated by a synchro connected to the planes. In addition, since the equipment limits the depth error voltage, only small depth changes can be made, enabling depth keeping but not depth changing.

22-83. OPERATION OF DEPTH KEEPING CONTROL (ADC)

The automatic depth control (ADC) system, in addition to maintaining constant depth, permits a submarine to make ordered depth changes automatically. This is accomplished by changing the limit of the error signal voltage on the DKC to the amount required for the ordered depth change.

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NAVAL SHIPS TECHNICAL MANUAL
formerly
Bureau of Ships Technical Manual

Chapter 50

Auxiliary Steam Turbines

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the damaged blade, and the blade diametrically opposite, shall be cut off at the junction of the vane portion and the root and the rotor checked for balance if practicable.

50-39. REDUCTION GEARS

(1) A turbine operates economically at a high speed whereas in some cases, the driven auxiliary is most efficient when operating at a low speed. To derive efficient results, each unit must operate at its approximate economical speed. To effect this requirement mechanical reduction gears are used. Reduction gears used with auxiliary turbines are of two types, namely, helical and worm. Helical gears are employed where the shaft of the driven auxiliary is mounted parallel to the shaft of the turbine. Worm gears are employed where the shaft of the driven auxiliary is mounted perpendicular to the shaft of the turbine. If the gears are aligned properly and satisfactory tooth contact is obtained when gears are first installed, little trouble should be experienced with auxiliary turbine reduction gears provided they are supplied with an ample quantity of clean lubricating oil.

(2) New gears, or gears which have been realigned, should be thoroughly worn in at low power before being subjected to the maximum tooth pressure of full power. Pitting, particularly along the pitch line, may occur in the first few weeks of service. This pitting usually ceases after this time and no further trouble is experienced. The only care necessary is to see that no flakes of metal are allowed to remain in the oiling system. Operation of the gears is not otherwise affected by the slight pitting.

(3) A properly operating gear has a certain definite sound, which the trained operator can easily recognize. The cause of any unusual noises should be investigated and the unit should be operated with caution until the cause is discovered and remedied. Vibration is caused by faulty alignment, bent shafts, damaged driven auxiliary, etc., or by improper balance. Gear wheels, pinions, and worms are balanced dynamically when the units are built. Unless damaged or corroded in service, or improperly erected, they should remain in balance. Indications of unbalance in the gear are manifested in unusual vibration and noise and unusual wear of bearings. The vibration may, however, be due to unbalance in the turbine or in the driven auxiliary. The turbine rotor is much more likely to be out of balance than the gears.

NOTE: If replacement of turbo-generator pinion and gear sets is believed warranted due to high noise levels, sound tests should be conducted and sound pressure levels in decibels in the frequency range 37.5 to 9600 c.p.s. should be taken. Two sets of readings should be taken; one set at the watch-standers station and one set 1-inch from the gear case at the point where the highest levels are noted. A frequency spectrum is required as a single wide-band level "overall" does not accurately determine the effect of noise. Two noises may have the same overall level yet one can be objectionable and the other not from a deafness avoidance standpoint.

The levels set forth in Table 2, Noise Category D, Section S1-10 of the General Specifications for Ships of the U.S. Navy, for machinery spaces, should be used as a guide for determining if replacement is required.

(4) The amount of wear of gear bearings shall not be allowed to become sufficiently great to cause incorrect tooth contact. (See Article 50-18 for rebabbitting of bearings.) It is essential, for proper operation of the gears, that the total tooth pressure be uniformly distributed over the total length of the tooth faces. This is accomplished by accurate alignment and adherence to the designed clearances. The designed center to center distance of the axes of the rotating elements should be maintained as close as practicable and in all helical gears the axes of pinion and gear shafts must be parallel. Nonparallel shafts concentrate the load on one end of a helix and may cause a feather edge on teeth, flaking, galling, pitting, or deformation of tooth contour or may break the ends of teeth.

(5) All gears are fitted with spray nozzles which spray oil on the meshing teeth. These spray nozzles shall be kept open at all times. No oil-spray apparatus, fitted for lubrication of gears, shall be altered or rendered inoperative without authority of the Bureau.

(6) Proper initial alignment, an adequate supply of lubricating oil at all times, proper clearances, and inspection for damages should prevent trouble from wearing and scoring of teeth. If, after all precautions, the lubricating oil supply should fail and the teeth become scored, the gears must be overhauled at the first opportunity.

(7) The teeth should never be dressed as long as the gear is operating satisfactorily, not even in case of excessive abrasion, until after every attempt has been made to rectify the alignment. The abraded portions of the teeth should be dressed only sufficiently to prevent scoring of meshing teeth. Steel scrapers or a fine file should be used and every precaution taken to remove all emery, filings, or abrasive material. No attempt should be made to remove deep pitting or galling. In the case of helical gears where both pinion and gear teeth have been damaged by foreign bodies, both should be relieved of all humps. Further spotting and scraping should be confined to the teeth of the gear wheel. The high spots will show more quickly on the pinion because they come in contact oftener.

(8) The instruction book for any particular installation will usually prescribe method and equipment for determining the alignment of gears. In service the best indication of proper alignment is good tooth contact and quiet operation.

(9) Tooth contact can best be checked by treating the pinion teeth with a light coating of metal marking, preferably Prussian blue, red lead, or copper sulphate, and rotating the pinion in mesh with the gear. Observe the tooth contact and, if necessary, make adjustments to obtain proper tooth contact. For helical gears 80 percent of the face width should make contact; the contact should be uniformly distributed along the entire face width of the tooth. Necessary adjustments may include rebabbitting or renewal of bearings or scraping of teeth. The scraping process is only useful to remove a local high spot or deformation. General scraping of teeth shall be avoided, as this is likely to make matters worse instead of better.

(10) Gear cases are sometimes provided with inspection plates so that rotating parts may be sighted. Tooth contact and condition of teeth should be examined at periodic intervals at the discretion of the engineer officer. Before inspection covers are removed, the vicinity of the opening

must be free of all nuts, bolts, tools, or other foreign matter that might fall into the gear case and cause damage. While gear cases are open, the openings shall never be left unattended unless satisfactory temporary closures have been installed. Before replacing an inspection plate, connection, fitting, or cover which permits access to the gear casing, a careful inspection shall be made by a responsible officer to insure that no foreign matter has entered, or remains in the casing.

50-40. GOVERNOR VALVE SEATS

(1) When turbines are dismantled for repairs or inspection, the condition of the governor valve seats should be checked. Where governor valve seats are found to be loose, they should be seal welded or silver soldered in place, if practicable. Also inspection of valve seats frequently discloses that seating areas are steam cut and eroded. When replacement valve seats are ordered, unless the plans already call for such, specify that the seating areas are to be faced with chromium-cobalt alloy.

(2) Loose governor valve seats on generator turbines may be caused by too sudden changes in steam temperature, since some generator turbines operate on saturated steam when in port and superheated steam when at sea. The sudden change in temperature might occur from not shifting the turbine to the superheated line until after the ship is well under way and the main steam temperature has reached well into the superheat range; or it might be caused by sudden drops of steam temperature in the line due to carry over of feed water. The change from saturated to superheated steam should be made at the time the propulsion turbines are being prepared for getting under way, and not after the ship has gone to sea and the steam temperature brought up to normal. Also, when shifting from the superheated to the saturated header, the change should be made at the time the propulsion turbines are being secured and the superheat temperature has been gradually reduced to about the saturated temperature. When starting a turbine, sufficient time should be taken to heat the steam chest gradually, keeping the rotor turning slowly, rather than to put full steam into the unit suddenly before such warming up can occur. In case of emergency, a quick start may be necessary but this method of starting should be avoided whenever practicable.

50-41. ACCUMULATION OF DEFECTS

Defects such as pitting of ball races, excessive clearance in bearings, excessive clearance between steam nozzles and rotors or misalignment of same, oil relief valve and oil system clogged with dirt, leaky valves, excessive wear in oil pumps, leaky packing, etc., should not be allowed to accumulate. Such accumulation is preventable by systematic inspection, test, checking of clearance, and periodic overhaul, together with proper operating procedure.

50-42. VIBRATION

(1) Vibration in a turbine is a positive indication that the unit is not in proper working condition, and as soon as this condition is noted, a thorough investigation should be made to determine the cause of the trouble. If the trouble is not immediately remedied and defects are allowed to accumulate, bearing and packing clearances become excessive, with consequent loss of oil and steam; the bearings and packing are soon ruined and if the turbine is kept in operation, further trouble may develop resulting in complete disablement of the unit.

(2) Vibration of a unit may be caused by —

(a) Loose or poorly lubricated bearings.
(b) Worn thrust bearings.
(c) Parts rubbing or binding.
(d) Driven unit out of balance.
(e) Driven unit out of alignment.
(f) Turbine rotor out of balance.
(g) Loose or broken foundation bolts.
(h) Carbon packing clearances too small.
(i) Bent shaft.

(3) Should a turbine vibrate to such an extent that an out-of-balance condition is suspected, the following steps should be taken:

(a) Examine bearings and renew if it is found that the clearance is excessive.

(b) Examine and if necessary adjust or renew the thrust bearing.

(c) Examine all parts for evidence of rubbing or binding.

(d) See if carbon packing clearances are satisfactory. If clearances are too small, the vibration will get worse if speed and temperature are kept constant; also, the shaft will overheat due to friction and start to show heating colors. Be sure that sufficient steam is being supplied to gland. Refit packing if necessary.

(e) Check alignment.

(f) Look for loose bolts in the unit and its support. Replace or tighten any that are found.

(g) Remove rotor and shaft, and check shaft in lathe for runout.

(h) After above steps have been taken and turbine is reassembled, run the unit at normal speed to determine if the vibration has been eliminated.

(i) If the turbine still vibrates, it may be assumed that it is still out of balance and a running balance must be made. This may be accomplished in place by use of the Davey vibrometer carried by tenders and repair ships, or by removal from the vessel and balancing at a naval shipyard. If Davey vibrometer is used, maximum readings on vibrometer scale should not exceed 0.003 inch.

50-43. CARE AND INSPECTION

(1) After each period of steaming, and in any case at least once a quarter, the turbine foundation and the unit itself shall be carefully inspected for loose or broken nuts or bolts. If any are found, they shall be renewed or tightened immediately.

(2) Concurrently with the above examination, care shall be exercised to inspect the turbine casing interior, especially near glands and in all locations where water may collect in pockets or under the lagging. Experience has shown that where water or dampness is permitted to remain in contact with the casings, the casings may be seriously weakened by corrosion before the situation is discovered. Where drain holes are provided in pockets, these holes must be kept open, and they should be of such size that they are not easily stopped up. Where indications of active corrosion are discovered, the affected surfaces should be properly bared and cleaned to good metal, re-

Chapter 60

Electric Plant—General

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working on equipment which has been deenergized by opening this breaker.

(j) Safety is attaching warning tags to handles of switches which must remain in "off" position while repairs of equipment connected to these switches are in progress.

(k) Safety is keeping unauthorized personnel away from electrical equipment opened for inspection test or servicing, a distance of 4 feet, if possible.

1. Safety is closing covers (and taping ends of exposed conductors) of electrical equipment under repair if necessary to leave it unattended before repairs are completed.

(m) Safety is wearing rubber gloves and rubber sleeves (lineman's) in addition to usual, welder's protective clothing when arc welding on weather decks with ship underway.

(n) Safety is using plastic-cased in lieu of metal-cased portable electric tools, when a choice exists.

(o) Safety is using rubber or plastic covered, in lieu of metal type, portable receptacles when a choice exists.

(p) Safety is following up oral safety instructions to a new man by going with him to each new type of electrical task assigned him and showing him the required safety procedures to make sure he has gotten the word.

(q) Safety is making sure that nobody working on top of the main switchboards (e.g. painters) climbs up or down the back of the switchboard. (Rig temporary barrier if feasible).

(r) Safety is keeping protective covers on electric and electronics equipment closed at all times except when they need to be open during actual inspection and servicing of the equipment.

(s) Safety is wearing high voltage rubber gloves and rubber (lineman's) sleeves when replacing high voltage electron tubes, resistors, fuses, etc. and if manipulating the interlocks of the removed panel covers to deenergize and energize the equipment. (Electric and electronic equipment, sonar, etc.). Note: Where intricacy of work makes wearing of gloves unfeasible, make doubly sure equipment is deenergized and stays deenergized—apply 3e, 3f, 3h and 3i.

(t) Safety is immediately notifying the Electric Shop of any portable or permanent electric equipment on which slight shocks are occasionally felt.

(u) Safety is notifying the Electric Shop of any bulkhead power receptacle, light, box, or other equipment which is observed to be in need of repair: loose cover, loose, broken or missing ports.

4. Always remember that:

(a) Electricity strikes without warning.

(b) Hurrying reduces caution and invites accidents.

(c) Taking time to be careful saves time in the end.

(d) Taking chances is an invitation to trouble.

(e) If you do not know the safe way, it pays to find out before exposing yourself to danger.

(f) Every electrical circuit, with but insignificant exceptions which definitely do not include circuits even as low as 35 volts and possibly even lower, is a potential source of danger and MUST BE TREATED AS SUCH.

(g) Except in cases of emergency, never work on an energized circuit. It must be considered that the circuit is energized until a personal check has been made to see that the switch is opened and tagged (See art. 60–36), and the circuit has been tested with a voltmeter, or voltage tester. (See art. 60–30).

(h) Energized switchboards are a great source of danger. No work shall be undertaken on switchboards (energized or deenergized) without first obtaining the approval of the Electrical or Engineer Officer. The Commanding Officer's approval shall be obtained prior to the commencement of work on an energized switchboard.

(i) Records show that seven out of ten victims of electric shock were revived when artificial respiration was started in less than 3 minutes after the shock. After 3 minutes the chances of revival decrease rapidly.

All shipboard personnel should be made aware of the fact that a victim rendered unconscious by electric shock should receive artificial respiration and that it should be started in a matter of seconds rather than minutes. To this end the person nearest the victim should start the resuscitation without delay and call or send others for assistance and medical aid. The only logical permissible delay is that required to free the man from his contact with the electricity in the quickest, safest way. This step, while it must be taken quickly, must be done with great care, otherwise there may be two victims instead of one. This should be done in the case of a portable electric tool, light, appliance, equipment, or portable outlet extension by turning off the bulkhead supply switch or by removing the plug from its bulkhead receptacle. If the switch or bulkhead receptacle cannot be quickly located, the suspected electric device may be pulled free of the victim by grasping the insulated flexible cable to the device and carefully withdrawing it clear of its contact with the victim. Other persons arriving on the scene must be clearly warned not to touch the suspected equipment until it is unplugged. Aid should be enlisted to unplug the device as soon as possible. Where the victim is in contact with stationary equipment such as a bus bar or the contacts on a machine, he should be pulled free if the equipment cannot be quickly deenergized, or if considerations of military operation or ship survival prevent immediate shutdown of the circuits. The man can be quickly and safely cleared from his contact with the electricity by carefully applying the following procedures:

In pulling him free, the principles reflected by the safety instructions of article 60-37 must be kept in mind. To save time, however, the equivalent of the protective insulation for the rescuer must be improvised. For example, instead of taking time to hunt for a pair of rubber gloves for use in grasping the victim, the victim can be safely pulled free if conditions are dry by grasping him by slack in his clothing or by the leather of his shoes. Instead of hunting for a rubber mat on which to stand, such nonconducting materials as deck linoleum, a pillow, blanket, mattress, dry wood, or coil of rope will suffice. In no case during the rescue should any part of the rescuer's person directly touch hull metal or metal structure or furniture.

(j) Additional information on safety is to be found in "Electric Shock-Its Causes and Its Prevention," NAVSHIPS 250-660-42.

60-23. RESUSCITATION FOR ELECTRIC SHOCK

Note: The following instructions on resuscitation were furnished by the Bureau of Medicine and Surgery.

Artificial resuscitation after electric shock includes artificial respiration to re-establish breathing, and external heart massage to re-establish heart beat and blood circulation.

To aid a victim of electric shock after removing him from contact with the electricity, immediately apply mouth-to-mouth artificial respiration.

If there is no pulse, immediately apply heart massage also.

Don't waste precious seconds carrying the victim from a cramped, wet, or isolated location to a roomier dryer, frequented location.

If desired, breathe into victims mouth through a cloth or a handkerchief placed over victim's face. If assistance is available, take turns breathing into victim and in massaging his heart. See figures 60-1, 60-2 and 60-3.

A. Cardiac Arrest (Loss of Heart Beat)

If the subject has suffered an electric shock and has no heart beat he will have a cardiac arrest. This can be demonstrated by finding a complete absence of any pulse at the wrist or in the neck. Associated with this the pupils of the eyes will be very dilated, respiration will be weak or stopped. The subject may appear to be dead. Under these circumstances severe brain damage will occur in four minutes unless circulation is re-established by cardiac massage.

B. Closed Chest Cardiac Massage

This method has been adopted as practical and can be learned by anyone who is properly instructed and requires only two hands. The object in closed chest cardiac massage is to squeeze the heart through the chest wall thereby emptying it to create a peripheral pulse. This must be done about 60 times each minute.

C. DIRECTIONS:

1. Place subject on his back; a firm surface, such as the deck, is preferred. Expose subject's chest.

Kneel beside victim; feel for lower end of subject's sternum (breastbone); place one hand across breastbone so heel of hand covers the lower part; place second hand on top of the first so that the fingers point toward neck as in figure 60-3.

3. With arms nearly straight, rock forward so that a controlled amount of your body weight is transmitted through your arms and hands to the breastbone. The amount of pressure to apply will vary with the subject. It should be applied as smoothly as possible. With an adult subject the chest wall should be depressed 2 to 3 inches with each pressure application.

4. Repeat application of pressure about 60 to 80 times per minute.

5. An assistant should be ventilating the subjects lungs preferably with pure oxygen under intermittent positive pressure; otherwise with mouth-to-mouth resuscitation. However, closed chest massage will cause some ventilation of the lungs. Therefore, if you are alone you must concentrate on the massage until help can arrive.

6. Direct other assistants when available to keep checking the potients pulse. Use the least pressure that will secure an effective pulse beat. The pupils will become smaller when effective cardiac massage is being performed.

7. Pause occasionally to determine if a spontaneous heart beat has returned.

8. Precautions: Make every effort to keep the hands positioned as described in order to prevent injuries to the liver, ribs or other vital organs. Since the heart cannot recover unless supplied with oxygenated blood it is necessary to accompany cardiac massage with mouth-to-mouth artificial respiration. When there is only one operator the cardiac massage must be interrupted every half minute or so to institute rapid mouth-to-mouth breathing for three or four respirations.

60–24. GROUNDING OF METAL PARTS AS A SAFETY MEASURE

Metal enclosing cases, bases, frames, and structural parts of electrical equipment which are not intended or expected to operate at potentials above ground potential should be grounded. Normally on steel-hull vessels such grounds are inherently provided because the metal enclosing cases or frames are in contact with one another and the metal structure of the vessel. Where such inherent grounding is not provided by the mounting arrangements, for instance, equipment supported on shock mounts which insulate it from the hull, and on wooden hull vessels, ground connections should be provided to ground the frame, enclosure, or support of all permanently installed electrical equipment and of all semiportable equipment which is normally used at a fixed location in the vessel. For the grounding of portable equipment, see articles 60-25 to 60-27 and 60-29. If enclosing cases and similar parts are not grounded, a breakdown of insulation may raise them to line voltage and create a hazard which is the more serious because it is unexpected. Such breakdowns from a circuit or machine to an ungrounded metal object will not be shown by ground tests or measurements of insulation resistance. They will be if the metal object is grounded.

60–25. GROUNDED TYPE PLUGS AND RECEPTACLES FOR METAL-CASED PORTABLE TOOLS AND EQUIPMENT

(1) Metal Case Type.

Navy specifications for metal-cased portable tools require the electric cord for the tool to be provided with a distinctively marked grounding conductor in addition to the conductors for supplying power to the tool. Except for a few cases in which black was used in the cords for some items of portable equipment, past practice was to use red for the grounding conductor in three-conductor cables for portable tools and equipment, and green in four-conductor cables. Revised specifications require that green be used for the grounding conductor in cables for all new metal-cased portable tools and equipment. The end of the grounding conductor which is within the tool should be connected to the metal housing; the other end should be grounded, that is, connected to the ship's metal structure. In order to provide a convenient means of connecting the grounding conductor to ground, the Bureau has standardized on the use of grounded type plugs and receptacles which automatically make this connection when the plug is inserted in the receptacle. The installation of grounded type receptacles has been authorized for all power outlets in surface vessels and for submarines. Where the grounded type receptacles have been installed, they should be used in conjunction with grounded type plugs (art. 60-27) to ground metal-cased portable tools and equipment.

(2) Plastic Case Type.

Non-conducting case type portable electric tools, plastic cased, shock proof, do not require grounding cords or plugs. The two conductor cords and two-prong ungrounded connector plugs furnished on these plastic-cased tools are acceptable and can be inserted in blade type receptacles aboard ship which may be labeled "WARNING: Insert 3-prong grounded plugs only."

(d) Clean ground contacts.

(3) Using a volt-ohmmeter, test the resistance from ships hull to face of ground contact (must be less than one ohm).

(4) Replace cover in proper relation to polarity and index pin.

(5) Insert type D-2-G Navy plug attached to an equipment or an adaptor, drawing 815-1197085. If an adapter is used, insert a commercial plug attached to an equipment into adaptor receptacle.

(6) Using a volt-ohmmeter, test resistance from housing of equipment to ships hull (must be less than one ohm).

b. **Receptacles – Bladed** – single outlet (used in lighting fixtures) and double outlet, drawings 9000-S6202-73274 and 9000-S6202-74263 and single, watertight outlet 9000-S6202-74456.

(1) Deenergize circuit, test to make sure that the receptacle is deenergized, and adopt all necessary precautions to make sure that it will stay deenergized until all tests at the receptacle, including (5) and (6) below, have been completed.

(2) Remove box cover and examine for the following:

(a) Correct type having two parallel slots and one U-shaped ground hole. Receptacle unit (drawing 9000-S6202-73274) having a blade type ground contact shall be replaced with duplex receptacles unit (FSN H5935-086-8924). Single receptacle unit installed in lighting fixtures shall have two parallel slots and one U-shaped ground hole. Replacements should be purchased from local suppliers.

(b) Correct wiring.

(c) Secure terminal screws.

(d) Clean ground contacts.

(e) Corrosion protection caps authorized for use in crew's heads and showers.

(3) Using a volt-ohmmeter, test the resistance from ships hull to the face of the ground contact (must be less than one ohm).

(4) Replace cover.

(5) Insert commercial grounded plug attached to equipment.

(6) Using a volt-ohmmeter, test resistance from housing of equipment to ships hull (must be less than one ohm).

(6) **Test of grounded receptacles.** To ascertain whether vibration, corrosion or some other cause has made a grounded receptacle unsafe, each grounded receptacle on a ship should be inspected and tested in accordance with article 60-26 (5). These tests should be performed as follows:

a. **Receptacles**

(1) **Detailed procedure:** It is recommended that the detailed procedures as outlined in article 60-26 (5) regarding receptacles be performed once on each ship, and thereafter be repeated only following an overhaul or other period during which derangement of these receptacles could have occurred.

(2) **Abbreviated procedure:**

(a) It is recommended that the following procedure be employed in making a routine ground continuity of each installed receptacle at least once a month.

1. Plug in any small 115 volt portable electric tool into the receptacle to be tested.

2. Secure one ohmmeter lead to the metal of the tool housing and the other lead to the ships hull.

3. The ohmmeter reading must be less than one ohm to indicate a satisfactory grounding circuit from the equipment housing through the plug and receptacle to the ships hull.

4. An alternate method of test is as follows: Connect one test lead of an ohmmeter or multimeter to the ground prong of a mating plug of the receptacles to be tested. The power prongs of this plug are to be left unconnected. Insert the plug into the receptacle to be tested. Touch the probe of the other test lead of the meter to ship's structure. The resulting reading should be less than one ohm.

(b) Unsatisfactory receptacles should be immediately repaired or be tagged to indicate that they must not be used.

(c) A record book should be kept on each ship giving the location of all grounded receptacles and the dates when they have been tested.

60–27. PLUGS AND CORDS

(1) **Cords for use with grounded plugs.** Some of the portable tools now in use on Naval vessels may not yet be provided with the grounded type plug. In addition, there is a wide range of miscellaneous portable electric equipment that may be issued without being provided with a cord that has a grounding conductor and a grounded plug. This equipment includes galley equipment (fruit juice extractors, food-mixing machines, coffee pots, toasters); office equipment (adding machines, addressograph machines); shop equipment (key duplicating machines, valve grinders, mica undercutters, hot plates); medical equipment (infrared lamps, ultra-violet lamps, sterilizers); barber shop equipment (hair clippers); laundry equipment (flatirons); and others. Except as indicated in article 60-27 (2) and (3):

(a) All 115-volt or 230-volt single phase a.c. and all 115-volt or 230-volt two-wire d.c. electrically operated equipment now on board ship which does not have a cord with a grounding conductor and grounded plug, and all such equipment subsequently issued to the ship without a cord which has a grounding conductor and grounded plug, should be provided with a three-conductor flexible cable with grounded plug except as indicated in article 60-25 (2) plastic type case. The three-conductor flexible cable should be type SO or ST color coded black, white, and green, as listed in the Navy Stock List of General Stores, Group 61. For general use, the plug should be bladed type with "U"-shaped grounding prong. These are stocked for small and large diameter cords under numbers G5935-280-2381. Stub-type plugs which can be made watertight when in use, formerly designed as type D-2-G, drawing 9-S-4440-L, are now furnished with plastic shell. They are identified by Bureau of Ships drawing 815-1197085, and the symbol numbers 701.1 or 720 for small and large diameter cords respectively.

(b) All 115-volt 3-phase electrically operated portable equipment now on board ship or subsequently issued, which does not have a cord with a grounding conductor and grounded plug, should be provided with a type FHOF four-conductor flexible cable color coded black, white, red, and green, with standard Navy grounded plug, type EEE-125, shown on Bureau of Ships plan 9-S-4861-L.

(c) The length of the cord for portable tools should be 25 feet. The length of the cord for such equipment as heaters should be as required. Extension cords (shown on Bureau of Ships plan 9000-S6202-73448) for use with portable tools and equipment are authorized for inclusion in the ship's allowance. These extension cords consist of 25 feet of three-conductor flexible cable (which includes the grounding wire) with a grounded plug attached to one end and a grounded type portable receptacle suitable for receiving the grounded type tool or equipment plug on the other end.

(2) **No change to be made just for the sake of color coding.** No change should be made in equipment now on board ship or subsequently issued which has a cord with a grounding conductor color coded in conformity with past practice. Such equipment should be used in accordance with past practice until cord replacement becomes necessary. Replacement cable should be type SO or SI for three-conductor cords, and type FHOF for four-conductor cords. The green conductor should be used for the grounding conductor. The plugs for three-conductor and four-conductor flexible cable are provided with a gland nut and packing which grips the cord securely and should prevent the cord from being pulled out of the plug under most conditions of rough usage.

(3) **Cords not to be replaced on equipment that is adequately grounded.** The cords need not be replaced on apparatus that is positively and adequately grounded through its mounting, nor on portable lights and other equipment having no exposed metal parts that may become energized. A two-conductor flexible cable and a plug suitable for use with the grounded type receptacle should be provided for such equipment. In addition, a check should be made to make sure that the natural grounding of the equipment is not blocked off in any way. For example, it was found that in one type of 8½-inch bracket fans used on submarines and smaller surface ships, the fan motor case is insulated from the fan base by a vibration mount. All fans of this type should be provided with a stranded ground connection from the motor case to the mounting bracket. Be sure to unplug all equipment grounded by direct contact with mountings or by a ground connection to mountings, **before** removing the equipment from mountings or disconnecting the ground connection; otherwise the ground is lost while the equipment and its case may still be a dangerous potential. Another method of ground consists of replacing the two-conductor cable from the base to the motor with a three-conductor cable. Two of the conductors are for carrying power to the motor; the third should be connected to the motor case at one end and to the mounting bracket at the other end. Electric shavers may be grounded where feasible and if desired by the owner.

(4) **Connecting cords and plugs.** In connecting the cord and plug, the grounding conductor of the cord should be connected to the ground contact of the plug at one end, and to the metal equipment casing at the other. Extreme care must be exercised to see that the ground connection is made correctly. If the grounding conductor which is connected to the metallic equipment casing is inadvertently connected to a line contact of the plug, a dangerous potential will be placed on the equipment casing. This will almost certainly cause a fatal shock to the man handling the portable equipment when it is plugged into a power receptacle since line voltage will be on the exposed parts of the portable, metal-cased equipment. This might easily result in a fatal shock to the operator. To guard against this danger, the connections should be tested after they have been made as described in article 60-27 (5).

(5) **Tests of plug connections.**–Before using portable electrical equipment for the first time, check the plug connections of the equipment for correct wiring. The following tests of portable equipment should be conducted in a workshop equipped with a nonconducting surface workbench and diamond tread rubber deck covering. Electricians making the tests should wear rubber gloves during tests.

(a) **Plug–NAVY TYPE.**-Drawing 9-S4440-L, Type D-2-G, or 815-1197085 symbols 701.1 and 720.

1. Examine and make sure that insulation and contacts are in good condition.

2. Examine and make sure that conductors are properly secured under terminal screws.

3. Examine to determine that the plug is clean and that all contacts are free of hangover fringes of moulding material that would prevent making good contact. Particular attention should be given to the ground contact.

4. Using a volt-ohmmeter, test resistance from ground contact to equipment housing (must be less than one ohm). Move or "work" cable with a bending or twisting motion. A change of resistance will indicate broken strands in the grounding conductor. If this is found, the coble must be replaced.

Check type D-2-G plug on equipment and extension cord. Using a megohmmeter, measure insulation resistance between brass shell and each contact on plug. Move or work cable with a push-pull, bending and twisting motion while taking reading. If resistance is less than one megohm, check for twisted bare wires in plug. Rewire defective plug and replace brass shell with nylon shell. if excessive wear and tear requires a plug to be replaced, accomplish by renewal of plug tip and replacing brass shell of plug with nonconducting plastic (nylon) plug shell. Do not re-use brass shells. Nylon plug shell is identified as drawing NR 815-1,197,085, stock number H5935-678-8520 for cables up to 0.425-inch diameter, and H5935-732-1841 for 0.560-inch diameter cables. If nylon plug shell is not in stock, rewire and retest brass-shell type plug for temporary use until nylon plug shell is available.

(b) **Plug–Bladed.**-Round or U-shaped contact.

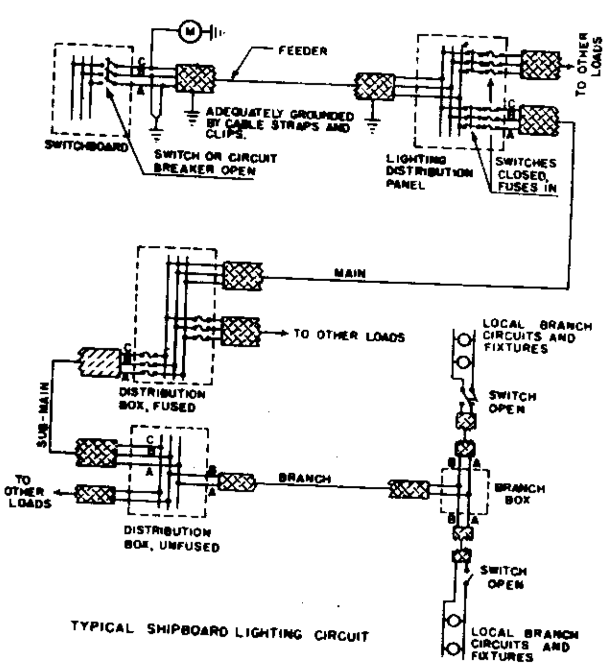
the terminals of the equipment, and those internal parts of the component apparatus which remain connected to the terminals such as bus bars, switches, fuse clips (fuses in place), etc. Be certain to disconnect equipment which cannot withstand the 500 volts applied by the megger.

(2) The circuits to be initially measured should be considered as beginning at the open switch or circuit breaker on the switchboard from which the potential is supplied and extending through closed switches on distribution panels and boxes, fuse clips (fuses in place), etc., to its extremity including the terminal lugs of controllers, light fixture switches, etc., as illustrated in figures 60-2 and 60-3. The legs or phase leads to be measured in the circuit should include the following:

(a) **Lighting circuits.** The legs or phase leads should include all panel wiring, terminals, connection boxes, fittings, fixtures, and outlets normally connected but with all plugs removed from the outlets.

Note: Where local lighting switches are double pole, the insulation resistance to ground and between conductors of local branch circuits and fixtures is not measured when the switch is open, since both conductors in each of the local branch circuits are isolated by the open switches. However, it can be determined whether grounds exist on local branch circuits and fixtures in such cases by making an insulation resistance test from one leg or phase lead to ground with the local switches closed. Circuit isolation shall be used only to the extent necessary to determine the cause of the low insulation resistance if the measured values are below the acceptable limits given in article 60-112.

(b) *Power circuits.* The legs or phase leads should include panel wiring, terminals, connection boxes, fittings, outlets (with all plugs removed), motor controller terminals, and other apparatus which remains connected when the



TYPICAL SHIPBOARD LIGHTING CIRCUIT

Figure 60-8.

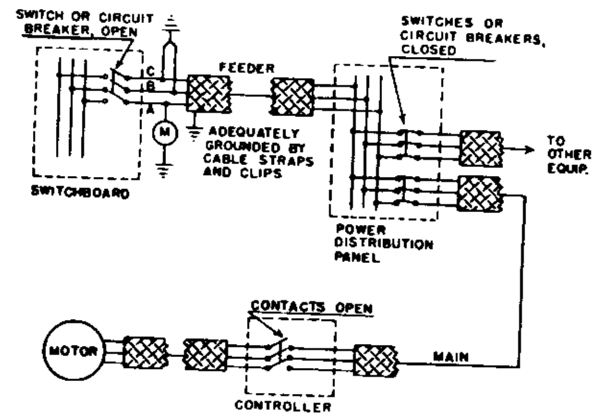


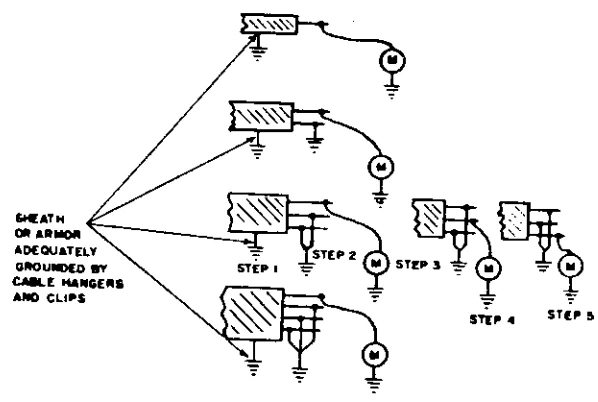
Figure 60-9.

phase lead or the leg is isolated by opening circuit breakers or switches at the switchboards and by leaving motor controller contactors open.

(c) *Degaussing circuits.* Measurements should be taken at a degaussing connection box. The legs should include the coil cables, through boxes and feeder cables. The supply and control apparatus should be disconnected by opening the circuit on the coil side of the control equipment (or motor generator set in installations of that type). Measurement of the compass coil feeder cable should be made with all control equipment disconnected. See chapter 81 for additional information on tests of degoussing installations.

(d) Measurements of circuits as defined above should be made on each individual leg of d.c. circuits and each individual phase lead of three-phase a.c. circuits. For example, measurements of three-conductor cable circuits should be as follows (see fig. 60-10):

Step 1. Ground the cable armor if not already grounded; normally this has been accomplished as part of the installation by means of the cable straps or other contacts between the armor and the metal structure of the vessel.



TYPICAL METHODS OF MEASURING INSULATION RESISTANCE OF CABLE CIRCUITS

Figure 60-10.

Step 2. Connect two legs or phase leads together and ground them by means of temporary wires or clipped test connections.

Step 3. Measure the resistance of the third leg or phase lead to ground.

Steps 4 and 5. Repeat steps 2 and 3 so as to measure each leg or phase lead to ground.

Note: For circuits containing permanently connected metallic paths between legs or phases (such as distribution transformers, instrument transformers, indicator lights, control relays, etc.) measurements need be made only between one conductor and ground, unless low values requiring further tests are obtained, in which case opening of additional connections and tests of individual legs or phases should be accomplished.

(3) The circuit insulation resistance values measured in accordance with the forgoing should be considered satisfactory if they are not less than the minimum values defined as the "basis of acceptance" in article 60-112.

(a) The minimum value obtained on this identical circuit (same cable and apparatus connected) at approximately the same ambient temperature of the cable location in any previous insulation resistance test, provided that value has been established as satsifactory by the further investigation as described hereinafter or by other investigation and satisfactory service operation shall be considered acceptable. If should be noted that if no previous value for this circuit has been established which may be used for comparison purposes, the further segregation and analysis of the cable and circuit components in accordance with procedures subsequently described will result in establishing a value that should be recorded on the resistance test record card (NAVSHIPS 531-1 (10-63 (see article 60-185 (3)) (Figs. 60-6 and 60-7) and used in insulation resistance tests conducted hereafter.

(b) Insulation resistance values need not be recorded except in those instances of minimum resistance values or when physical damage has occurred and/or whenever there is evidence of a contaminant having leaked on the cables. Records may be destroyed when it has been ascertained that the situation has become satisfactory as evidenced by a constant acceptable value of insulation resistance when measured daily for one week.

(4) In those instances where the insulation resistance of a circuit is less than the minimum value described in art. 60-112, the low value may be due to trouble localized in a segment of the circuit. To determine whether this is the case, segregate the circuit into two or more parts by opening switches, circuit breakers, removing fuses, etc., at the feeder distribution panels and boxes. Conduct insulation resistance tests on each segment of the divided circuit in accordance with the foregoing instructions. One or more of the segments may indicate abnormally low insulation resistance as compared with other segments of approximately equivalent length and extent. If such is the case, the relatively low reading value obtained on the segment of the circuit may be due to low insulation resistance at the cable junction with terminals, or in apparatus remaining connected. This possibility should be investigated by inspecting and checking all cable junctures, apparatus (Fixtures, fittings, wiring appliances, etc.) remaining connected in the phase lead or leg of the segment in question. Possible causes of low insulation resistance such as faulty connections, accumulations of dirt, foreign materials, etc., should be corrected by cleaning or corrective action as necessary. After this inspection and cleaning the insulation resistance of the phase lead or leg should be measured again and the value compared with values obtained before inspection and cleaning.

Part 4. Insulation in Rotating Electric Machinery

60-131. FACTORS WHICH AFFECT INSULATION RESISTANCE

The insulation resistance of the windings on a piece of rotating electric machinery is affected by the construction of the machine, moisture, temperature, cleanliness, and age and condition of the windings.

1. **Construction.** Dimensions, shape, number of turns, type of insulation, and process of manufacture, all influence the insulation resistance of a winding. Windings in large or low voltage machines will have inherently lower insulation resistances than those in small or high voltage machines. Field windings will have inherently higher values than d-c armature windings or a-c phase windings. Under equivalent conditions d-c armature windings will have lower insulation resistance than phase windings of a-c machines of equivalent capacities due to the numerous creepage paths at the commutator connections. The insulation resistance of class A insulation is inherently lower than of class B insulation. The types of bonding and coating varnishes and the drying processes used also have considerable influence. Duplicate machines constructed in the same shop will differ in their insulation resistance because of the variations that occur in their manufacture.

2. **Moisture.**

a. When insulation stands in a moist atmosphere, it absorbs moisture and its insulation resistance decreases. The amount of moisture absorption is increased by increased time of exposure or by an increase in the relative humidity of the atmosphere. It also depends upon the type of insulation and its condition. Cotton, paper, and asbestos insulating materials absorb moisture more readily than mica. Vacuum-pressure impregnated windings usually seal out moisture more effectively than built-up or immersion-impregnated windings. Insulation that has cracked or is otherwise damaged usually is more susceptible to moisture absorption.

b. Since moisture may be driven off or evaporated by the application of heat, the insulation resistance of a winding having a low resistance due to the pressence of moisture may be restored by energizing or externally heating the winding. However, if in addition to the moisture the insulation has deteriorated from exposure to oil, acid, or other harmful matter, the insulation resistance probably cannot be restored to its original value.

3. **Temperature.**

a. As in the case of cables (art. 60-111 (3),) the insulation resistance of the windings on rotating electric machinery decreases as the temperature of the insulation increases. Insulation resistance measurements taken at intervals can be properly compared only when taken at ap-

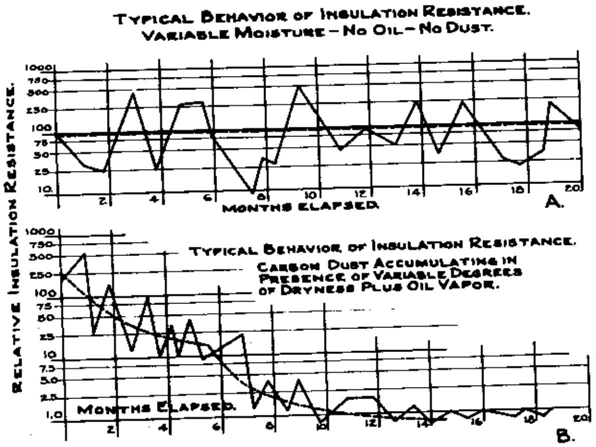


Figure 60-12.

trend of insulation resistance values. The resistance test record card (NAVSHIPS 531) (Rev. 8-48) provides a convenient form upon which to draw the curves. Figures 60-12, 60-13, and 60-14 show the general trend which may be obtained over a period of time for large d.c. motors and generators. If records are to be kept, a new curve should be started for each machine every time the machine is given a thorough cleaning by yard, base, or tender force or after each yard, base, or tender overhaul. It should be noted that the ordinates of figures 60-12, 60-13 and 60-14 are plotted with a logarithmic scale. The logarithmic scale is plotted only on NAVSHIPS 531 (Rev. 8-48).

60–136. INTERPRETING MEASUREMENTS OF INSULATION RESISTANCE

When the insulation resistance level of a machine falls below that allowed in article 60-324, it is necessary to interpret the meaning of these new levels.

The following conclusions based on practical service experience should be of assistance in understanding what values and variations in insulation resistance may be considered normal and abnormal and in deciding what corrective measures should be taken when abnormal conditions are encountered:

1. New machines or new windings may have relatively low values of insulation resistance and still be perfectly fit for service. See art. 60-131 (5) (b).

2. After the period of time required for the varnish to dry out has elapsed, the insulation resistance of a winding or circuit in good condition may be expected to decrease gradually with age if no variations in moisture content, temperature, or cleanliness occur. See article 60-131 (5) (a).

3. Periodic tests in service are useful in detecting weaknesses of insulation or accumulations of moisture or dirt. Such conditions are usually indicated by marked decreases in insulation resistance. Hence periodic measurements serve to determine when cleaning, drying or other servicing of the machine is necessary.

4. A high value of insulation resistance is not always proof that the insulation is in good condition. See article 60-131 (5) (b). For this reason, complete and thorough inspections should be made regularly in addition to the periodic tests of insulation resistance.

5. When measuring resistance, if the instrument pointer requires appreciable time to reach a steady value, the insulation is usually relatively dry and clean. If the instrument pointer becomes steady quickly and the resistance is low, there is a strong possibility that the insulation is moist, dirty, or damaged.

60–137. MINIMUM VALUES OF INSULATION RESISTANCE

When the insulation resistance level of a machine falls below that allowed by article 60-324, tests of sub circuits are performed. The allowable levels of the sub circuits are somewhat different and are tabulated in article 60-139.

It is impossible to set a rigidly fixed value for the minimum permissible insulation resistance on a machine and state positively that if the machine 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. Machines can and have operated satisfactorily over extended periods of time with low insulation resistance. Conversely, a high value of insulation resistance is alone not sufficient to insure satisfactory operation. Nevertheless, despite those limitations, past experience has made it possible to set up limiting values of insulation resistance which serve to indicate the values that should be maintained on machines in service, and also serve to determine the nature of the treatment that should be given electrical equipment when it is overhauled. These values are shown in tables 1 to 4, inclusive, which are explained in articles 60–138 to 60–141, inclusive.

60–138. EXPLANATION OF TABLES

The following tables list insulation resistance levels of the isolated machine or circuit.

Tables 1 to 4 give insulation resistance values for four types of machine. For each machine, three sets of insulation resistance values are given, before cleaning, after cleaning in the vessel, and after reconditioning in a shop. The following notes contain information which should be kept in mind when using the tables.

1. All figures are for insulation resistance values at 25° C. (77° F.). If measurements are made at temperatures different from 25° C., the measured values should be corrected to 25° C. by the use of the alinement chart given in figure 60-6. See article 60–131 (3) (c) for instructions on the use of this chart.

2. All figures are **minimum** values. Insulation resistances well above the minimum values are normally obtainable. Every reasonable effort should be made to **maintain insulation resistances at values considerably** higher than those given in the tables.

3. The complete armature circuit of a d-c machine includes the armature, brush rigging, connections to machine terminals, and any fields which carry armature current, such as commutating field, compensating field, and series field.

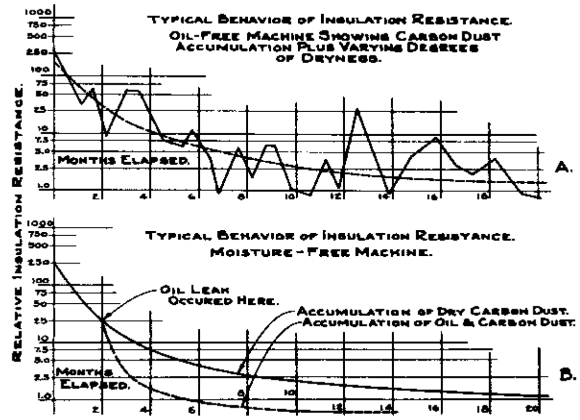


FIGURE 60-13.

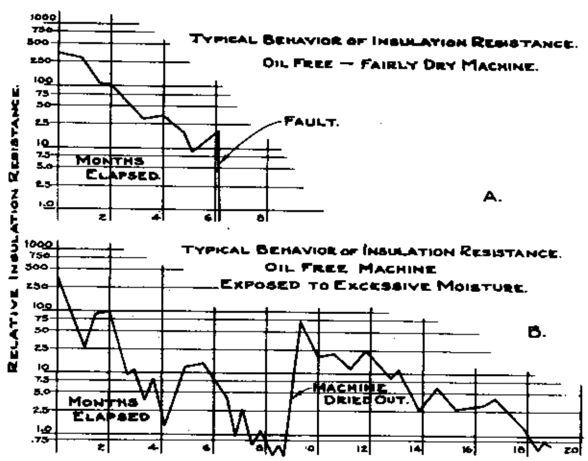


FIGURE 60-14.

4. The stator circuit of polyphase generators and motors and the rotor circuit of wound rotor induction motors includes all phases. When a single phase is isolated (see art. 60-133), its insulation resistance should be at least three times the value given in table 3 or 4 if the machine has three phases, or at least two times if the machine has two phases (used in some electric propulsion equipment).

5. The word "Cleaning" as used in tables 1 to 4 inclusive includes thorough cleaning of the machine and such maintenance as drying the machine by means of external heat, by energizing the windings or by the use of a desiccant and does not include such minor maintenance as wiping commutators or slip rings.

60-139. INSULATION RESISTANCE OF MACHINES IN SERVICE

The following tables list minimum allowable insulation resistance levels of the isolated machine or circuit under various conditions.

The figures given in the "Before cleaning" columns of tables 1 to 4 are the values of insulation resistance at or below which machines should be removed from service and thoroughly cleaned, dried out, or repaired as necessary. Values less than those given in the "Before cleaning" columns should not be construed as necessarily indicating an unsafe condition or one which would prohibit the use of a machine if necessary. However, when values less than those are obtained for a machine, use of the machine should be avoided if practicable and action should be taken at the first opportunity to find and remedy the cause of the low insulation resistance. Very often the cause of abnormally low insulation resistance may be suspected from the nature of the operating conditions prior to the test which showed low insulation resistance.

TABLE 1. —*Direct-current generators and motors (except propulsion generators and motors and auxiliary generators for submarines)*

Circuit	Insulation resistance in megohms at 25° C.[1]		
	Before cleaning	After cleaning in vessel	After reconditioning in shop
Complete armature circuit[2]	0.1	0.5	1
Armature alone	0.2	1	2
Armature circuit less armature[2]	0.2	1	2
Complete shunt field circuit[2]	0.5	1.25	2.5

1 The figures given are for machines rated at 250 volts or less. For machines having a rated voltage, *E*, greater than 250 volts, multiply all figures given in the table by *E/250*.

2 Small machines usually have one of the shunt field leads connected internally to the armature circuit. To avoid disassembly in such cases, the complete armature circuit and complete shunt field circuit may be measured without breaking this connection. If necessary, the armature can then be isolated by lifting all brushes.

(a) With the brushes left in place, the complete armature circuit will include armature, armature circuit, and the permanently connected shunt field circuit. The values given in the table for the complete armature circuit will apply.

(b) With the brushes lifted, the armature circuit less armature and the complete shunt field circuit will be measured. The values given in the table for armature circuit less armature will apply.

commutating and compensating winding is then disconnected pole by pole and each pole is measured separately. It is found that one commutating field pole has lower insulation resistance than any of the other commutating field poles. Upon further investigation it is found that one of the less accessible spots on the pole has not been adequately cleaned, and after this place is cleaned, the insulation resistance of the pole in question is measured and found to be equal to all of the other poles. All parts of the armature circuit less armature are then reconnected and the insulation resistance measured, giving a value of 1.8 megohms which is greater than 1.0 megohm, indicating that these parts are satisfactory for service. The armature is then connected in the circuit and the complete armature circuit gives a measured insulation resistance value of 0.75 megohm which is greater than 0.61 megohm, and the complete armature circuit is ready for service.

(3) *Shunt field circuit.* The measured value of insulation resistance of the complete shunt field circuit before cleaning is 0.10 megohm which is less than 0.82 megohm, the value in the "before cleaning" column. Each shunt field coil is disconnected and tested separately and one coil is found to have much lower insulation resistance than any of the other coils. This coil is removed and it is found that the insulation between the coil and the metal pole piece has been damaged, allowing a low resistance path to ground. The damaged insulation is renewed and all of the shunt field coils cleaned and reconnected. The insulation resistance then measures 3.5 megohms which indicates that the complete shunt field circuit is ready for service.

SECTION IV. MAINTENANCE OF ELECTRICAL EQUIPMENT

Part 1. General

60–181. SAFETY PRECAUTIONS WHILE WORKING ON ELECTRICAL EQUIPMENT

Before attempting any maintenance or repair work on electrical equipment, be sure the equipment is disconnected from the power supply and that it cannot be inadvertently energized by some one who does not know of the work being performed. If there is any doubt as to whether the supply circuits have been deenergized, they should be checked with a voltmeter or voltage tester. Check the wiring diagram to determine if there are any condensers that should be discharged by connecting their terminals to each other and to ground by use of a wire on an insulating handle. An exception to the rule for deenergizing the equipment may be made when it is necessary to observe operation. In this case, observe the safety precautions necessary to prevent shock or arcs which might start fires or ignite explosive vapors. Refer to articles 60–21 to 60–50 for general electrical safety precautions.

(2) If an electrically-powered auxiliary must be operated manually at the same time that the associated controller must be energized to facilitate the location and correction of faults, the following procedure should be observed:

(a) Deenergize the controller at the supply panel.

(b) Disconnect the motor leads from the line contactor in the controller and insulate (tape) the terminal lugs.

(c) Check circuits to component equipment (such as brakes) to make sure that malfunctioning of the component (such as release of brake) cannot occur when the control circuit is energized. Disconnect leads if necessary.

(d) Energize the controller.

(e) When the fault has been located and corrected, deenergize the controller and reconnect leads.

(f) Make sure that all master switches are in the "off" position and that the equipment is properly set for power operation before again energizing the controller.

60–182. PURPOSE OF MAINTENANCE

(1) The purpose of maintenance is to make sure the equipment is in all respects ready for service at all times.

(2) The following are some primary considerations for satisfactory operation of electrical equipment:

(a) All circuits are connected correctly;

(b) Electrical contacts are clean, tight, and of low resistance;

(c) Moving parts function freely and in the way they are designed to operate; and

(d) Electrical insulation is in good condition– clean, dry, and of high resistance.

(3) The following articles describe measures which are intended to reduce future repairs to a minimum. They should be considered as "preventive maintenance" and, as such, have been kept at a minimum in order that their cost will not be out of proportion to the cost of future repairs. Due to varying conditions which may be found on different ships, judgement should be used as to where preventive maintenance should exceed the amount specified herein or, where conditions warrant, tests may be made at less frequent intervals.

60–183. PERIODIC CLEANING AND INSPECTION

A regular schedule of cleaning and inspection will go far toward insuring trouble-free operation and the detection of incipient faults before they develop sufficiently to be a major source of difficulty. Where definite times for cleaning and inspection are not specified in the instructions given in this chapter for different types of equipment, each ship should set up a practicable schedule for periodic cleaning and inspection at intervals sufficiently short to keep the equipment in good shape. In setting up such a schedule, the following points should be kept in mind:

(1) New equipment should be carefully watched until extended operation has demonstrated that it is performing satisfactorily.

(2) Old equipment requires more frequent cleaning and inspection than similar equipment which has seen less service.

(3) Time spent in cleaning, inspecting, and correcting defects before they grow serious means time saved in overhauls and repairs.

60–184. PERIODIC CHECK OF EXPLOSIONPROOF ENCLOSURES

(1) The gaps between the joint surfaces of explosionproof, group D, enclosures for electric equipment should be checked periodically, at least once every six months and at each overhaul, to ensure that they do not exceed safe

limits. An explosionproof, group D, enclosure is one so constructed as to withstand without distortion or other injury, an explosion of atmospheres of gasoline, petroleum ether, alcohol or natural gas – but not acetylene hydrogen, manufactured gases, ethyl either or dust – occurring within its, and to prevent emission therefrom of sparks, flashes, flame, or hot products of combustion which may ignite surrounding or adjacent conbustible or explosive material. Plane gaps may be checked with thickness gages such as are carried as Federal Stock Nos. GM 5210-242-3926, GM 5210-221-1984, GM 5210-274-2857, GM 5210-221-1985, and GM 5210-221-1986. Gap clearances should not exceed:

(a) Plane joints—0.010-inch.

(b) Stepped joint, cylindrical surfaces—0.004-inch radial (0.008-inch diametral) where the plane fit is less than 1/4-inch wide; 0.008-inch radial (0.016-inch diametral) where the plane fit is 1/4-inch or more wide.

(c) Shafts of motors—0.016-inch radial (0.032-inch diametral) for shafts centered by ball or roller bearings; 0.008-inch radial (0.016-inch diametral) for shafts not so centered. These dimensions are somewhat greater than those under (a) and (b) above because the bearing structure is usually stronger and clearance must be adequate to permit shaft rotation.

(2) If the clearances indicated above cannot be met, the equipment should be replaced with equipment which does meet these requirements. It will be noted that the above gaps exceed those permitted in present purchase specifications for electric equipment. This is due to normal deformation and deterioration which can be expected in service. In no case should these gaps be gasketed or painted since this would destroy the basic function of the gap. As suggested by the above definition, electric equipment which is explosionproof, group D, should not be used in explosive atmospheres of acetylene, hydrogen, manufactured gases, ethyl ether or dusts.

(3) In addition to checking the gap clearances, the effectiveness of the stuffing tube leading into the enclosure should also be checked.

(4) Relative to the general maintenance of explosionproof enclosures, it is obvious that holes should not be drilled through explosionproof enclosures, enclosure parts should not be machined in such a manner as to decrease the gap length (as contrasted to thickness) and hence flame path, bolts should not be omitted nor permitted to become loose, and bolts of diameter smaller than the original should not be used.

Although time-proven explosion-proof enclosures are still a basic choice where hazardous areas are involved, there are other approaches which have found limited application on board ship. Two of these approaches are:

a. Sealing. These designs are usually identifiable by the seal which is in contrast with the heavy-duty, unsealed flanges of explosion-proof enclosures. Two methods of sealing are:

(1) Completely filling the voids of the equipment with a fluid. This is the approach which has been taken in the case of submersible pumps and similar equipment.

(2) Hermetic sealing. These enclosures are rigid, of non-porous material such as metal, glass, or ceramics, and sealed by a fusion process such as soldering or welding.

b. Intrinsic safety. Intrinsically safe equipment and circuits are defined as being incapable of releasing sufficient electrical energy under normal or abnormal conditions to cause ignition of a specific hazardous atmospheric mixture. Items in this category have very low power ratings and are appropriately labeled. They usually have either a self-contained power supply (such as a dry-cell battery) or an arrangement which separates them physically and electrically from the main power source.

The maintenance requirements for explosion-proof equipment obviously do not apply to either of the above approaches.

60-185. RECORDS AND REPORTS

(1) Maintenance records add greatly to the value of inspection. Records which reveal progressive deterioration and repetition of repair jobs indicate the necessity for a deeper investigation into the cause of trouble. Reports based upon such records form the basis for changes in design, application, or method of operation to eliminate future faults and difficulties, increase the ease and dependability of operation, and ensure the safety of personnel and long life of equipment. The records and reports which are of particular importance in connection with maintenance of equipment are the ship's material history, the current ship's maintenance projects, and derangement reports.

(2) **Material history card – electrical**

(a) A history should be kept on each ship on material history cards–electrical (NAVSHIPS 527A), with a separate card for each major item of power and lighting equipment. Examples of items for which cards should be kept are:

Propulsion generators and exciters.
Propulsion motors.
Propulsion control cubicles and stands.
Ship service and emergency generators and exciters.
Electrically driven forced draft blowers, lube oil purifier motors, boiler feed pump and condensate pump motors, steering gear motors, etc.
Magnetic minesweeping generators, exciters, and control equipment.

(b) When the card for an item is full, the history should be continued on another card. The history kept on the card should include a complete record of all measurements and tests such as air gap, power output or input, speed measurements, and of any other tests made on the equipment; of all difficulties, troubles or derangements; of the methods used to restore the equipment to service; of the dates when grease or oil were changed; and of all work done on the equipment whether by the forces afloat, at a naval shipyard, or elsewhere. All pertinent data and dates should be entered. Entries should be arranged in chronological order.

(3) **Resistance test record card.** In addition to the history card, a resistance test record card (NAVSHIPS 531-1 (10-63) may be kept for power, lighting, and degaussing circuits. For recording data on each item of electrical rotating machinery which is essential to the continued opera-

tion of the ship's propulsion plant, use resistance test record card having the logarithmic plotting scale (NAVSHIPS 531 (Rev. 8-48)). Examples of such equipment are:

Propulsion generators and exciters.

Propulsion motors.

Magnetic minesweeping generators and exciters.

(4) Derangement reports. Derangements of electric power and lighting equipment should be reported to the Bureau of Ships on material analysis data cards (NAVSHIPS 3621). A thorough report should be prepared even if the derangement is considered to be due to faulty installation, operation, or maintenance rather than defective design or manufacture. Such information is needed to design equipment which will reduce or eliminate the possibility of similar occurrences. Facts are wanted together with comments on the cause and results of the trouble. A report which merely states that a failure has occurred furnishes no information upon which to base action to prevent similar failures in the future. A report should include, in full detail, observations made prior to, during, and after the failure. See chapters 65 and 71 for items to be covered in reports of trouble with interior communication and fire

air gaps larger than 0.040 inch. Test the air gap by trying to push this strip all the way from one end of the air gap to the other. This test should be made at four points 90° apart, if possible, and if not, at a number of points (not less than three) spaced at approximately equal intervals around the circumference. The test can be repeated with a slightly thicker strip if a closer estimate is needed.

4. It is more important to have uniformity of air gaps at all points than to have the gap conform exactly to the specified limits. If the air gap at any of the places tested differs from the average air gap by more than 20 percent for average air gaps smaller than 0.040 inch, or by more than 10 percent for average air gaps larger than 0.040 inch, the bearings should be realigned, repaired, or replaced. Usually an inequality of air gaps which is not greater than specified above will not cause unsatisfactory operation. If, however, trouble is experienced, such as vibration or excessive noise which cannot be traced to any other cause than unequal air gaps, it is advisable to realine, repair, or replace bearings to equalize air gaps, even if the measured inequalities are within the limits given.

60-291. LUBRICATION OF SLEEVE BEARINGS

1. Every precaution should be taken to keep the oil and bearings clean and free from water or foreign particles.

2. Do not add oil while the machine is running. This affords an opportunity for oil mist or spray to escape from the bearing housing and be blown on the machine windings.

3. Bearings having an overflow gage should be filled until the oil is about one-sixteenth inch from the top of the gage. If the machine is equipped with an oil filler gage, the gage should be filled to the manufacturer's oil level mark, or (if no mark is available) the gage should be between two-thirds and three-quarters full at all times. Be sure that the gage glass and piping to the gage are clean or the glass will give false indications of the oil level. If the bearing has neither an overflow gage nor an oil filler gage, fill to a level such that the oil ring dips into oil to a depth of about half the shaft diameter.

4. When the bearing and bearing housing are in good condition, there should be no loss of oil. If the proper oil level cannot be maintained without adding oil, it is probable that oil is leaking from the bearing. Be sure oil sight gage connection to bearing is tight. Much of the oil that leaks out of a bearing is drawn into the machine by the cooling air and sprayed onto the windings where it causes oil soaked dirt to collect. This condition tends to cause insulation failure. If oil leakage is suspected, carefully clean and chalk the shaft outside the bearing, the outside of the bearing housing, and the parts of the rotor adjacent to the bearing. If the machine is throwing oil, discoloration of the chalk will so indicate after a short run. This test will not be dependable unless the chalked part is perfectly clean at the beginning of the test. If leakage is found, the labyrinth seal in the bearing housing should be corrected to make it effective. Another possible source of leakage is from the vent with which some labyrinths are provided. Make sure that any such vent is not stopped up and that it terminates in still air of atmospheric pressure where there is no current of air over the vent that will suck oil out of the bearing housing or oil vapor out of the vent into the machine. Such oil leakage is often due to overfilling the bearing or trying to fill the bearing through the vent.

5. Bearing oil should be renewed semiannually. Drain the oil off by removing the drain plug, then flush the bearing with clean oil until the drained oil flows clean.

60-292. INSPECTION OF BEARING SURFACES AND OIL RINGS IN SLEEVE BEARINGS

The inspection opening at the top of the bearing should be removed periodically to check the condition of oil rings and bearing surfaces. The oil ring should rotate freely when the machine is running and should not stick because of the motion of the ship. The bearing surface should not be pitted or scored.

60-293. BRUSHES

(1) ***Brush grade and adjustment.*** The correct grade of brush and correct brush adjustment are necessary to avoid commutation trouble. For good commutation:

(a) Use the grade of brush shown on the drawing or in the technical manual applicable to the machine, except where Bureau of Ships Instructions issued after the date of the drawing or technical manual (such as the instructions for brushes to be used in electric propulsion and magnetic minesweeping equipment) state otherwise. In such cases, the Bureau of Ships Instructions should be followed. Most of the brushes in shipboard service are of a grade which have satisfactorily passed rigid tests at a Government laboratory and appear on the Qualified Products List as complying with one of six Military grades, S, A, H, D, G, and E. In the case of propulsion and magnetic minesweeping equipment, only one grade of each of two different brush manufacturers is permitted for any machine. This restriction on brush interchangeability is based on the vital nature of the machines involved and on the impracticability of factory testing these machines while operating with several manufacturers' grades which have been qualified under any one of the six military grades.

(b) All brush shunts should be securely connected to the brushes and the brush holders.

(c) Brushes should move freely in their holders but should not be loose enough to vibrate in the holder.

(d) The following brushes should be replaced with new brushes, the replacement being preceded by cleaning all dirt and other foreign material from the brush holder:

1. Brushes which are worn or chipped to such an extent that they will not move properly in their holders.

2. Brushes which have damaged shunts, shunt connections, or hammer clips.

3. Brushes having riveted connections or hammer clips and are worn to within 1/8 inch of the metallic part.

4. Brushes having tamped connections and without hammer clips and worn to one-half or less of the original length of the brush.

5. Brushes having spring-enclosed shunts and worn to forty percent or less of the original length of the brush exclusive of the head which fits into one end of the spring.♦

(e) Where brush springs are of the positive gradient (torsion, tension, or compression) type and are adjustable, they should be adjusted as the brushes wear, in order to keep the brush pressure approximately constant. Springs of the coiled band, constant pressure type and certain springs of the positive gradient type are not adjustable except by changing springs. Brush pressure should be in accordance with the manufacturer's technical manual. Pressures as low as 1-1/2 pounds per square inch of contact area may be specified for large machines and as high as 8 pounds per square inch of contact area may be specified for small machines. Where technical manuals are not available, a pressure of 2 to 2-1/2 pounds per square inch of contact area is recommended for integral horsepower and integral kilowatt machines, and about twice that pressure for fractional horsepower and fractional kilowatt machines. To measure the pressure of brushes operating in box type brush holders, insert one end of a strip of paper between the brush and commutator; use a small brush tension gage (such as the 0 to 5 pound indicating scale carried in General Stores under No. GS6670-583-0063) to exert a pull on the brush in the direction of the brush holder axis. Note the reading of the gage when the pull is just sufficient to release the strip of paper so that it can be pulled out from between the brush and commutator without offering resistance. This reading divided by the contact area may be considered to be the unit operating pressure. Taking correction factors into consideration, the actual pressure will be a few percent lower in the case of brushes operating in the leading position and a few percent higher in the case of brushes operating in the trailing position.

(f) All brush holders should be the same distance from the commutator, not more than one-eighth inch, nor less than one-sixteenth inch.

(g) The toes of all brushes on each brush stud should line up with each other and with the edge of one commutator segment.

(h) The brushes should be evenly spaced around the commutator. To check brush spacing, wrap a strip of paper around the commutator and mark the paper where the paper laps. Remove the paper from the commutator, cut at the lap, and fold or mark the paper into as many equal parts as there are brush studs. Replace the paper on the commutator and adjust the brush holders so that the toes of the brushes are at the creases or marks.

(i) Brushes should be staggered as shown by the correct method in figure 60-16 to prevent grooving of the commutator. The incorrect method of staggering, shown in figure 60-16, gives unsatisfactory results because the pitting effect is different under positive and negative brushes. For machines having a number of poles equal to two times an odd number, it will obviously not be possible to stagger all the brushes in accordance with the correct method. Stagger all but the odd pair of positive and negative brushes in accordance with the correct method, and the odd pair in accordance with any two adjacent rows in the incorrect method figure 60-16. There is no need to stagger brushes when the machine has only one row of brushes (one brush holder per brush holder arm).

(j) The brush surface in contact with the commutator should be an accurate fit. See article 60-294 for instructions on fitting brushes.

(2) *Indications and Causes of Unsatisfactory Brush Performance.* The following outline covers most of the indications and causes of unsatisfactory brush performance in typical shipboard d.c. motors and generators. The remedy is usually self-evident when the cause is identified and is, therefore, omitted from the outline. The numerous causes listed opposite most indications may be confusing at first glance. Usually, however, there will be more than one indication of a faulty condition. The problem of finding the right cause can be simplified by first investigating those causes which are common to all observed indications.

Indications:	*Causes:*
Indications appearing at brushes:	
Rapid brush wear:	Humidity to low.
	Incorrect spring pressure.
	Wrong brush grade.
	Brushes too tight in holders.
	Brushes too loose in holders.
	Brush holders loose at mounting.
	Coefficient of friction too high.
	Presence of vapors from Class H insulation.
	Loose or unstable foundations.
	Environmental vibration.
Brush chipping or breaking:	Brushes too tight in holders.
	Brushes too loose in holders.
	Brush holders loose at mounting.
	Commutator loose.
	Environmental vibration.
	(See Chattering or noisy brushes.)

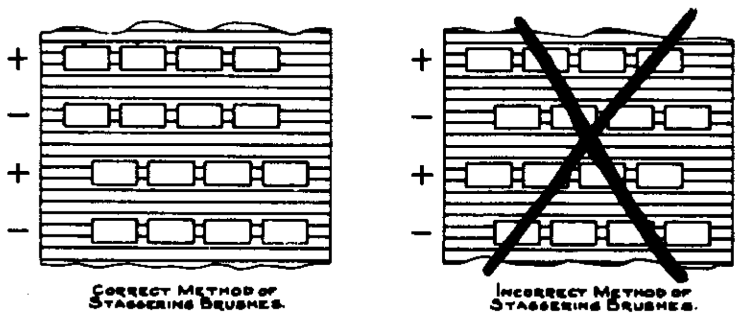


FIGURE 60-16.

practicable, and thoroughly inspected for tightness of electrical connections and mechanical fastenings.

(4) Wiring distribution boxes (fused) with and without switches which feed vital circuits should be checked annually. Tighten fuse clip barrel nuts and terminal connections. On a new ship and after a major overhaul, tighten and prick punch loose bus bar nuts on the backs of insulating bases.

(5) In 1960 the phosphor-bronze fuse clip and supplementary bent-wire fuse retainer were superseded by a steel, copperclad silver-plated fuse clip. The steel fuse clips do not require fuse retainers to prevent dislodgement of fuses under shock and vibration. The wire fuse retainers impose a hazard of possible accidental dislodgement and falling into buswork to cause short circuits. To eliminate this hazard on both vital and nonvital circuits that require frequent removal of fuses, and where difficulties are occuring with loosening of existing phosphor bronze fuse clips and wire fuse retainers, they should be replaced with steel copper clad silver plated fuse clips as follows:

Type Designation	Federal Stock Number
FC21C (Midget)	N5940-752-6723
FC21D (30 amperes)	N5940-752-6500
FC21E (60 ampere)	N5940-752-6501

Do not remove the wire retainers until the new type steel fuse clips are on board for substitution. Tighten the fuse-clip barrel nut until the arch in bottom of the steel fuse clip is drawn flat.

60-352. CLEANING SWITCHBOARDS AND DISTRIBUTION PANELS

(1) Wiping with a dry cloth will usually be sufficient for cleaning bus bars and insulating materials. A vacuum cleaner, if available, can also be used to advantage. Care should always be exercised to make sure that the switchboard or distribution panel is completely dead and will remain dead until the work is completed. Cleaning live parts should be avoided because of the danger to personnel and equipment. Always observe electrical safety precautions when cleaning or working around switchboards. (See arts. 60-21 to 60-50.)

(2) Soap and water should not be used on the front panels of live front switchboards or on other panels of insulating material. Use a dry cloth.

(3) The front panels of dead front switchboards may be cleaned without deenergizing the switchboard. Wiping with a dry cloth is usually all that is needed to clean the panels. A damp soapy cloth may be used for grease and finger prints. The surface should then be wiped with a cloth dampened in clear water to remove all soap and dried with a clean, dry cloth. The cloths used in cleaning must be wrung out thoroughly so that no water is left to squeeze out and run down the panel. A small area at a time should be done and then wiped dry.

60-353. CIRCUIT BREAKERS, CONTACTORS, AND RELAYS

(1) Circuit breakers should be carefully inspected and cleaned at least once a year (more frequently if subjected to unusually severe service conditions) and oil should be changed in oil film type overcurrent tripping devices every 6 months (art. 60-353 (3) (d)). A special inspection should be made, particularly of the contacts, after a circuit breaker has opened a heavy short circuit. BEFORE WORKING ON A CIRCUIT BREAKER, ALL CONTROL CIRCUITS TO WHICH IT IS CONNECTED SHOULD BE DEENERGIZED. DRAW-OUT CIRCUIT BREAKERS SHOULD BE SWITCHED TO THE OPEN POSITION AND REMOVED BEFORE ANY WORK IS DONE ON THEM. DISCONNECTING SWITCHES AHEAD OF FIXED MOUNTED CIRCUIT BREAKERS SHOULD BE OPENED BEFORE ANY WORK IS DONE ON THE CIRCUIT BREAKER. WHERE DISCONNECTING SWITCHES ARE NOT PROVIDED TO ISOLATE FIXED MOUNTED CIRCUIT BREAKERS, THE SUPPLY BUS TO THE CIRCUIT BREAKER SHOULD BE DEENERGIZED, IF PRACTICABLE, BEFORE INSPECTING, ADJUSTING, REPLACING PARTS, OR DOING ANY WORK ON THE CIRCUIT BREAKER. IF THE BUS CANNOT BE DEENERGIZED, OBSERVE THE PRECAUTIONS OF ART. 60-37.

(2) *Contacts* in circuit breakers, contactors, relays, and other switching equipment should be clean, free from severe pitting or burning, and properly alined. Occasional opening and closing of contacts will aid cleaning and sealing. Remove surface dirt, dust or grease with a clean cloth moistened, if required, with a small amount of inhibited methyl chloroform. Be sure that ample ventilation is provided if inhibited methyl chloroform is used (see arts. 60-413 and 60-414). Remove all traces of residue left by inhibited methyl chloroform. When cleaning and dressing contacts, maintain the original shape of the contact surface and remove as little material as possible. ←

(a) Inspect copper contact surfaces for black copper oxide film, and clean with fine sandpaper (No. 00), if required. Severely burned or pitted copper contact surfaces should be dressed with a fine file or fine sandpaper.

(3) *Circuit breaker mechanism.*

(a) Clean all surfaces, particularly insulation surfaces, with a dry cloth or air hose. Be sure that water is blown out of the air hose, that the air is dry, and that pressure is not over 30 p. s. i. before directing on the breaker.

(b) Check pins, bearings, latches, and all contact and mechanism springs for excessive wear or corrosion and evidence of overheating. Replace parts where necessary.

(c) Slowly open and close circuit breakers a few times manually. See that trip shafts, toggle linkages, latches, and all other mechanical parts operate freely and without binding. Make sure that the arcing contacts meet before and break after the main contacts. If poor alignment, sluggishness, or other abnormal condition is noted, adjust in accordance with the technical manual for the circuit breaker.

(d) Lubricate bearing points and bearing surfaces, including latches, with a drop or two of light machine oil. Wipe off excess oil.

(e) Before returning a circuit breaker to service, inspect all mechanical and electrical connections including mounting bolts and screws, draw-out disconnect devices, and control wiring. Tighten where necessary. Give final cleaning with cloth or compressed air. Operate manually ←

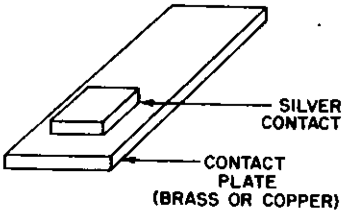


Figure 60-22. Contact assembly

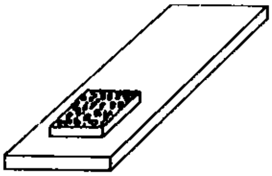


Figure 60-23

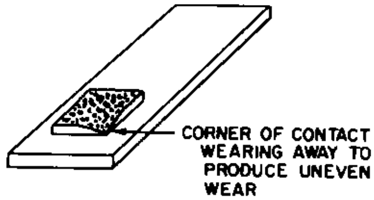


Figure 60-24.

to make sure that all moving parts function freely. Check insulation resistance.

(4) *Sealing surfaces* of circuit breaker, contactor, and relay magnets should be kept clean and free from rust. Rust on the sealing surfaces decreases the contact force and may result in overheating of the contact tips. Loud humming or chattering will frequently warn of this condition Light machine oil wiped sparingly on the sealing surfaces of the contactor magnet will aid in preventing rust.

(5) *Oiling.* Oil should always be used sparingly on circuit breakers, contactors, motor controllers, relays, and other control equipment, and should not be used at all unless there are specific instructions to do so or oil holes are provided. If working surfaces or bearings show signs of rust, the device should be disassembled and the rusted surfaces carefully cleaned. Light oil may be wiped on sparingly to prevent further rusting. Oil has a tendency to accumulate dust and grit which may cause unsatisfactory operation of the device, particularly if the device is delicately balanced.

(6) *Arc chutes* or boxes should be cleaned by scraping with a file if wiping with a cloth is not sufficient. Replace or provide new linings when broken or burned too deeply. See that arc chutes are securely fastened and that there is sufficient clearance to insure that no interference occurs when the switch or contactor is opened or closed.

(7) *Shunts and flexible connectors* which are flexed by the motion of moving parts should be replaced when worn, broken, or frayed.

60-354. OPERATING TESTS

Operating tests consisting of operation of equipment in the manner in which it is intended to function should be made regularly. Items of equipment should be tested as described below.

(1) *Circuit breakers.* For manually operated circuit breakers, the test consists of simply opening and closing the breaker to check mechanical operation; for electrically operated circuit breakers, the test should be made with the operating switch or control to check both mechanical operation and control wiring. CARE MUST BE EXERCISED DURING THESE OPERATING TESTS NOT TO DISRUPT ANY ELECTRIC POWER SUPPLY VITAL TO THE OPERATION OF THE SHIP NOR TO ENDANGER SHIP'S PERSONNEL BY INADVERTENTLY STARTING MOTORS, ENERGIZING EQUIPMENT BEING REPAIRED, OR OTHERWISE.

(2) *Bus transfer equipment.* For manual bus transfer equipment the test is made by manually transferring a load from one power source to another, checking mechanical operation and mechanical interlocks. For semiautomatic equipment, the test should also include operation by the control push buttons. For automatic equipment, the test should include operation initiated by cutting off power (opening a feeder circuit breaker) to see if an automatic transfer takes place. The precautions given above for circuit breaker operating tests should be observed when testing bus transfer equipment.

(3) *Overload relays.* During periodic inspections of motor controllers, or at least once a year, the overload relays should be examined to determine that they are in good mechanical condition and that there are no loose or missing parts. The size of overload heaters installed should be checked to determine that they are of the proper size as indicated by the motor nameplate current and heater rating table. Proper allowance should be made for short-time and intermittent-duty motors by using undersized coils. Any questionable relays should be checked for proper tripping at the next availability and replaced if necessary. Each relay should be checked for tripping time at 300 percent rated current by a naval shipyard at intervals not exceeding 4 years. In making this test, current flow through the overload relay must be interrupted at the instant tripping occurs to prevent damage to the relay. See Chapter 63 for a description of the various types of overload relays.

(4) *Control circuits* should be checked to insure circuit continuity and proper relay and contactor operation. So many types of control circuits are installed in naval vessels that it is impracticable to list any definite operating test procedures. In general, certain control circuits, such as those for the starting of motors or motor generator sets, or voltmeter switching circuits, are best tested by using the circuits as they are intended to operate. When testing such circuits, the precautions listed in article 60-181 (2) should be observed to guard against damage to the associated equipment. Protective circuits such as overcurrent, or reverse current circuits usually cannot be tested by actual operation because of the danger to the equipment involved. These circuits should be visually checked and, where possible, relays should be operated manually to make sure that the rest of the protective circuit performs its desired functions. Extreme care must be taken not to disrupt vital power service nor to damage electrical equipment. Reverse power relays should be checked

Chapter 9621

Electric Power Distribution System

List of Effective Pages

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1 - 3	Original
31 - 32	Change 1
33 - 37	Original

Original: 1 April 1966
Change 1: 15 January 1967

may be used as feeder breakers in some installations. Since these breakers can interrupt the fault current, they can also replace the ACB "back up" breakers. AQB breakers are used on the load side of AQB-LF breakers. If the AQB breaker has a smaller frame size than the AQB-LF breaker and the AQB breaker cannot interrupt the fault, the AQB-LF breaker will. If there is cable with sufficient impedence and the AQB-LF breaker, the AQB-LF breaker fuses will limit the fault current thereby protecting itself and the AQB breaker in series when the fault current is higher than the AQB breaker can interrupt. A fault at B would trip the feeder breaker, but not the generator or bus tie breakers. A fault at C would trip both bus-tie breakers. A fault at D, on switchboard No. 1, would trip No. 1 generator circuit breaker and one or both of the bus-tie breakers. In each case, the faulted section of the system is isolated, but power is continued on as much of the system as possible in view of the location of the fault. The circuit breaker settings which give best protection are naturally not the same in all installations. For full information on a specific installation, it is necessary to refer to the ship's plan, which shows circuit breaker time-current characteristics for that ship in curves similar to those in figure 9621-9.

6. Attainment of selective tripping requires careful coordination of the time-current characteristics for different circuit breakers. For example, if the system illustrated in figure 9621-8 is operating "split plant" (bus-ties open) and if the bands shown in Figure 9621-9 for the ACB feeder breaker and ACB generator breaker were interchanged, a fault at B in Figure 9621-8 would trip the No. 1 generator off the line, but would leave the feeder connected to the switchboard. This would cut off power to all equipment served by No. 1 switchboard, but would not isolate the faulted section. Consequently, unauthorized changes should not be made in circuit breaker trip settings since the scheme of protection based upon selective tripping could be completely disrupted. Adjustments are made at the factory and sealed.

9621.64. CIRCUIT PROTECTION WITH FUSES

It is not feasible to provide system protection by selective tripping of circuit breakers on all types of naval ships or for all circuits. For instance dc distribution systems on older ships and all lighting circuits use fuses almost entirely. Time delay can be incorporated only insofar as fuse characteristics permit. Progressively larger fuse sizes from load to generator give some degree of selectivity for overload or limited fault protection. Care should be exercised in the replacement of fuses to ensure that:

1. fuses are of the proper voltage rating
2. fuses are of the proper interrupting capacity
3. for special fast acting fuses supplying electronic equipment there may be no equivalent types. In which case, replacement fuses must be identical.

9621.65. VOLTAGE AND FREQUENCY PROTECTIVE MONITORING

Electronic equipment can be damaged by continued operation under abnormal voltage or frequency conditions. The 400-cycle systems on new ships are, therefore, checked by voltage or voltage and frequency monitoring devices. Occasionally, this may also be done on 60-cycle systems. When the voltage or frequency exceeds allowable limits for a predetermined length of time, the power supply circuit breaker is tripped. When the generator bus is being monitored, the device senses both voltage and frequency and is set to trip the generator breaker. When the devices are monitoring the output of a line voltage regulator, the device senses only voltage and is set to trip the circuit breaker supplying that line voltage regulator. When protective devices are installed, they are set to interrupt the supply within 0.25 seconds when the voltage or frequency exceeds the transient limits. Where monitors are installed, interruption will be initiated under the following conditions:

Types I and II Power
- Overvoltage: In excess of 125 percent ± 5 percent of nominal voltage.
- Undervoltage: Below 75 percent ± 5 percent of nominal voltage.
- Overfrequency: 430 ± 5 cycles per second for 400 cycle systems and 65 ± 1 cycles per second for 60 cycle systems.
- Underfrequency: 370 ±5 cycles per second for 400 cycle systems and 55 ± 1 cycles per second for 60 cycle systems.

Type III Power
- Overvoltage: In excess of 115 percent ± 5 percent of nominal voltage
- Undervoltage: Between 85 and 90 percent of nominal voltage
- Overfrequency: 420 cycles or over
- Underfrequency: 380 cycles ± 5 cycles or less

SECTION II. OPERATION

9621.71. CHARACTERISTICS OF ELECTRICAL INSTALLATION

The characteristics built into naval electrical installations are simplicity, ruggedness, reliability, and flexibility to permit continued service after part of the equipment has been damaged. It is the function of those who operate these plants to make full use of their inherent capabilities, and to maintain, as far as possible, uninterrupted availability of electric power where it is needed. To be able to do this, operating personnel should possess:

1. through knowledge of operation and maintenance of the component parts of the electric plan
2. complete familiarity with the electric plant as a whole
3. comprehensive understanding of system operation
4. ability to apply general principles to specific installations
5. knowledge of a few simple rules of system operation which are applicable to all naval installations.

9621.72. INSTRUCTIONS FOR SPECIFIC ITEMS

Instructions for specific items of electrical equipment are to be found in other chapters of this manual and in manufacturers' technical manuals. See particularly:

Chapter 9400 .... Tables of Engineering Data
Chapter 9410, Section IV ..... Electric Propulsion Installations

Chapter 9600	Electric Plant-General
Chapter 9610	Electric Generators and Voltage Regulators
Chapter 9621	Electric Power Distribution System
Chapter 9622	Portable Storage Batteries and Dry Batteries
Chapter 9623	Submarine Storage Batteries
Chapter 9630	Electric Motors and Controllers
Chapter 9640	Lighting
Chapter 9650	Interior Communication Installations
Chapter 9660	Searchlights
Chapter 9670	Electronics
Chapter 9690	Electrical Measuring and Test Instruments
Chapter 9710	Fire-Control Installations
Chapter 9814	Degaussing Installations
Chapter 9850	Motion Picture Equipment
Chapter 9920	Welding and Allied Processes

9621.73. FAMILIARITY WITH ELECTRICAL SYSTEM

Familiarity with the electrical system as a whole can be gained by study of information relating specifically to that installation. Valuable information on a ship's electrical installation is to be found in the Ship Information Book, Particularly Volume 3 for power and lighting systems and in the book of "onboard plans" carried by the ship, in training aid booklets, and in manufacturers' technical manuals supplied with many items of equipment. Study of these should be supplemented by a thorough study of the system itself so that generators, switchboards, distribution panels, and cables are not merely symbols on a plan but physical entities, the location of which is definitely known, whose functions and relations to the rest of the system are thoroughly understood.

9621.74. GENERAL PRINCIPLES OF SYSTEM OPERATION

General principles of system operation serve as a guide to the procedures which should be followed to maintain continuous availability of electric power. The general principles considered here relate to:

1. Split plant operation
2. Choice of power source
3. Prevention of overloads
4. Operation under casualty conditions

9621.75. SPLIT PLANT OPERATION

1. Consider a ship with two or four ship service switchboards, operating under battle conditions with all bus-ties closed and all generators running in parallel. A hit on switchboard No. 1, for example, or on a load center or cables connected to switchboard No. 1 may cause a short circuit. This will draw current from all generators, will momentarily affect the entire system, and may trip all generators off the line and result in a temporary loss of all ship service power. System protection is provided for the purpose of localizing the fault (see article 9621.63), but automatic protective devices, unfortunately, do not always function as intended. In addition, the overcurrent protective systems are not designed on the basis of handling the available fault currents when all the ships service generators are operated in parallel. (Refer to Ship Information Book, Volume 3). For this reason, the best arrangement for preventing loss of all power is to operate "split plant," that is with all bus-ties open. Each switchboard with its generators and loads then forms a system independent of the others. A hit on switchboard No. 1 will result in loss of power for the loads fed from this switchboard, but will not affect the loads fed from the others.

2. Split plant operation should, therefore, be used under battle or other conditions for maximum assurance against loss of all ship service power. If a switchboard is fed by two or more generators and if some of the generators are lost, split plant operation can be continued by using the remaining generators to supply power for some of the loads fed from the switchboard, and shifting other loads normally fed from the switchboard to alternate feeders connecting to other switchboards (see article 9621.12 (6)). If all generating capacity for a switchboard is lost, the bus-tie circuit breakers can be closed to energize the switchboard from one of the others. The chief utility of the bus-tie connection is obtained when all generating capacity for one switchboard is lost, or when operating at light loads at anchor or under cruising conditions such that a temporary loss of all ship service power could not endanger the ship.

9621.76. CHOICE OF POWER SOURCE

When both normal and alternate feeders are installed to a load, the normal source of power should be used except when loss of part or all the generating capacity at the switchboard supplying normal power makes it advisable to shift to the alternate source (see articles 9621.75 (2) and 9621.78 (1)).

9621.77. PREVENTION OF OVERLOADS

1. Sole reliance is placed upon the vigilance of the operator to guard against moderate overcurrents and power overloads which, if long continued, would cause excessive heating of generators. Ammeter readings will reveal the presence of overcurrents; wattmeter readings, of power overloads.

2. If a switchboard controls two or more generators and less than the full number is being used to supply power, the load on the switchboard may increase to a point which will overload the generators in use. When the switchboard instruments reveal this condition, or when it is anticipated very soon, another generator should be added. (See Chapter 9610 of this manual for instructions on the operation of generators.)

3. Emergency switchboards are connected by feeders to loads which may sometime need emergency power. The emergency generators are not of sufficient capacity, however, to provide power for the simultaneous operation of all loads

Chapter 62 (Sec. II)

Electric Power Distribution

List of Effective Pages

Page & Current Status	
1 - 6	Original
7	Change 1
8 - 31	Original
32	Change 1
33 - 36	Original

Original: 1 November 1965
Change 1: 15 January 1967

Class	Dimensions (over all in inches)			Number of plates per cell	Gallons electrolyte required to fill to normal level per cell	Weight charged (pounds)	Manufacturer's life guarantee (minimum cycles)
	Height	Length	Width				
6V-SBM-15AH------------	7-1/16	4-5/8	4-3/4	5	.2	15	600
2V-SBP-20AH------------	5-1/2	4	3	11	.1	4	150
6V-SBM-50AH------------	10-1/2	9-3/8	7-1/8	7	.275	52	500
6V-SBM-100AH-----------	10-1/2	16-5/16	7-1/8	17	.55	82	500
6V-SBMD-130AH ----------	11	16-5/16	7-1/8	27,29	.625	92	150
6V-SBM-200AH-----------	16-3/16	20-1/8	6-13/16	15	1.141	190	600
6V-SBMD-205AH ----------	10-7/16	25-3/8	7-1/8	41	.99	150	150
6V-SBM-300AH-----------	16-3/16	20-1/8	9-1/16	21	1.65	255	600

62-203. REACTIONS DURING CHARGE AND DISCHARGE

The exact nature of the chemical reactions which take place in a cell is rather involved, but the following brief description will give some idea of what occurs during a cycle of discharge and charge:

(1) When a cell is fully charged (Fig. 62-7 (a)), the active material of the positive plate is in the form of lead peroxide, PbO_2, and of the negative plate pure sponge lead, Pb. The specific gravity of the electrolyte (sulphuric acid, H_2SO_4, and water, H_2O) is at its maximum. Chemical energy is stored in the cell in this condition.

(2) If an external circuit is closed between the positive and negative terminals of a cell current begins to flow due to the action of the electrolyte upon the active material. The chemical energy thus is transformed into electrical energy, and the cell is said to be discharging (Figure 62-7 (b)). **The electrolyte reacts with the active material** to form lead sulphate on both the positive and negative plates. As the discharge progresses, the acid content of the electrolyte becomes less and less as it is used in forming lead sulphate, and the specific gravity of the electrolyte as read by the hydrometer therefore decreases. A point is reached where so much of the active material has been converted into lead sulphate that the cell can no longer produce sufficient current (electrical energy) to be of practical value and at this point the cell is said to be discharged. (Figure 62-7 (c).) Since the amount of sulphuric acid combining with the plate at any time during discharge is in direct proportion to the ampere hours of discharge, hydrometer readings can be used as a guide in determining the state of discharge of a lead-acid cell.

(3) If the discharged cell is properly connected to a direct current charging source, of voltage slightly higher than that of the cell, current will flow through the cell in the opposite direction to that of discharge and the cell is said to be charging (Fig. 62-7 (d)). The effect of the current will be to change the lead sulphate on both the positive and negative plates back to its original active form of lead peroxide and sponge lead, respectively. At the same time, the sulphate is restored to the electrolyte with the result that the specific gravity of the electrolyte increases. When all the sulphate has been restored to the electrolyte, the specific gravity will be a maximum. The cell is then fully charged, and is ready to be discharged again. It is always to be remembered that the addition of sulphuric acid to a discharged storage battery *does not recharge the battery*. Adding acid increases the specific gravity of the electrolyte but it does not *convert* the lead sulphate on the plates back into active material, sponge lead and lead peroxide, and consequently does not bring the battery back to a charged condition. A charging current must be passed through the battery to do this.

(4) The combined reactions during charge and discharge may be represented by the relation:

$$Pb + PbO_2 + 2H_2SO_4 \underset{\text{Charging}}{\overset{\text{Discharging}}{\rightleftarrows}} 2PbSO_4 + 2H_2O$$

(5) In addition to the above reactions, as a battery charge nears completion, hydrogen gas, H_2, is liberated at the negative plate, and oxygen gas, O_2, at the positive plate. This is because the charging current is greater than is necessary to reduce the small remaining amount of lead sulphate on the plates, and the excess current applies itself to the electrolysis of the water in the electrolyte. This is necessary to assure full charge to the battery.

Part 2. Shipment and Storage

62-211. FACTORY INSPECTION OF STORAGE BATTERY ←

All material entering into the construction of a storage battery is carefully inspected by Naval Inspectors to insure that the batteries shipped from the factory conform with Navy Specifications.

62-212. CONDITION OF BATTERIES ON SHIPMENT

(1) Batteries are shipped in one of the following conditions:

(a) Filled and charged

(b) Dry and uncharged.

(c) Dry and charged.

(2) When shipped filled and charged, the cells are completely assembled, contain electrolyte, are sealed, fully charged, and ready for use.

(3) When shipped dry, the battery is assembled and sealed, with separators in place, but contains no electrolyte. The plates are in the uncharged condition. Such batteries require filling and an initial charge to place them in commission.

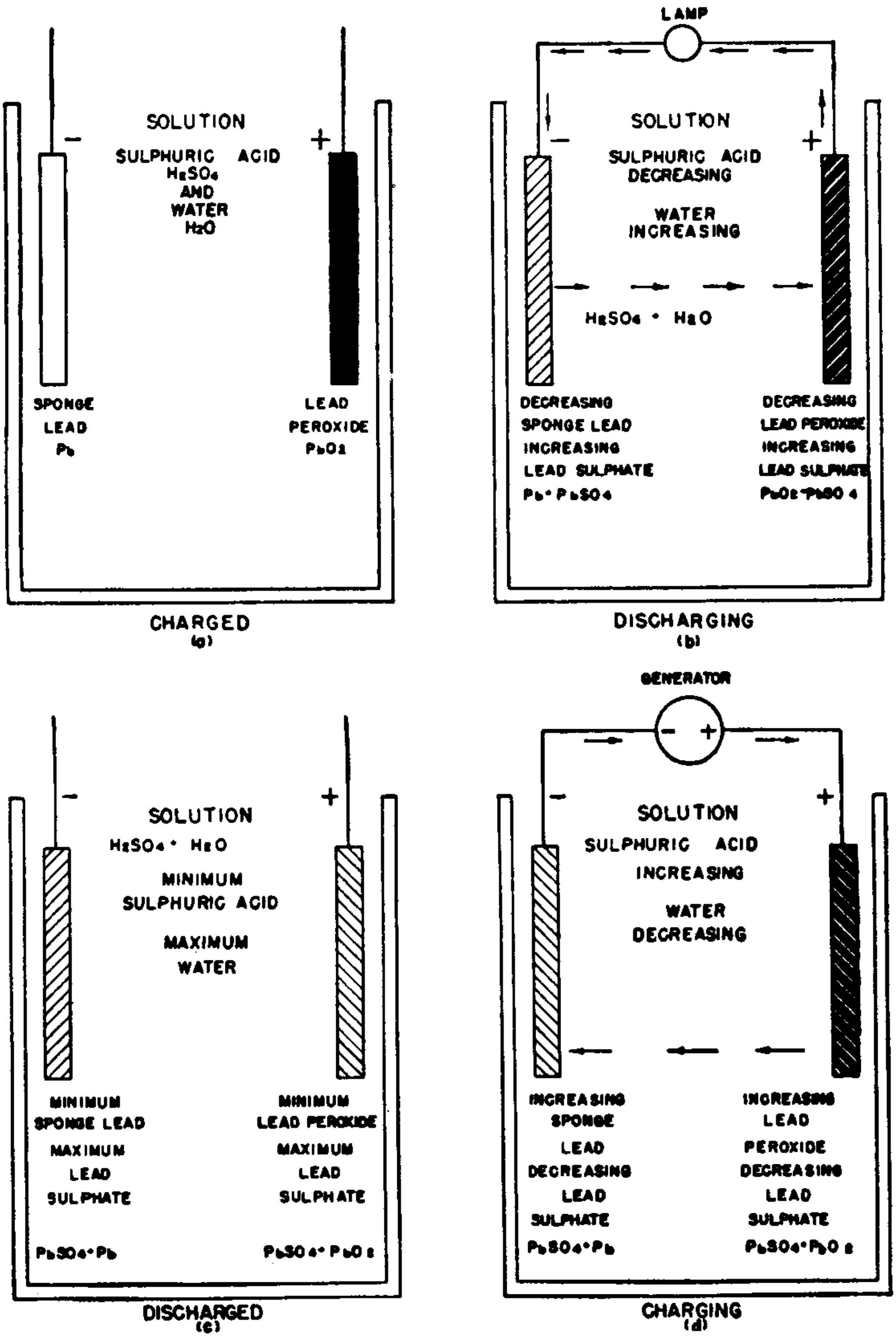

Figure 62-7 (a), (b), (c), and (d). Chemical reactions during charge and discharge.

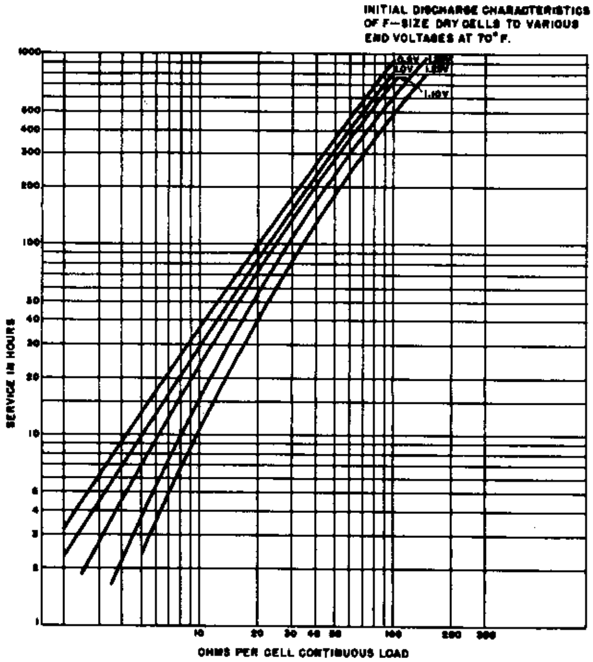

Figure 62-14 (f). Initial discharge characteristics of size F Leclanche cell at 70° F.

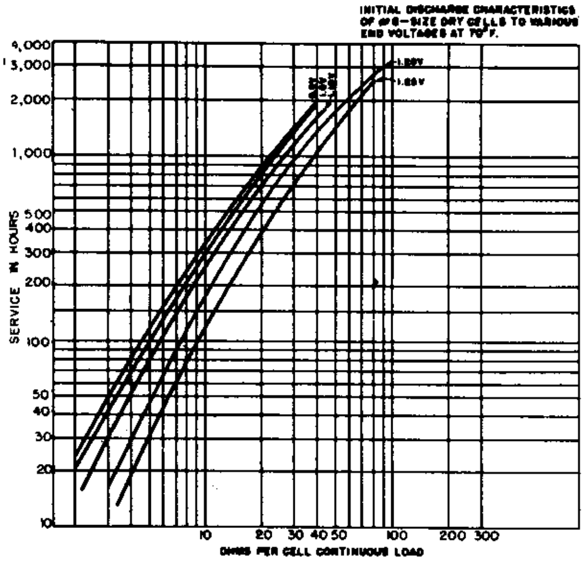

Figure 62-14 (g). Initial discharge characteristic of size No. 6 Leclanche cell at 70° F.

through 5 ohms/cell for 2.2 hours before the voltage falls to 1.25 volts per cell. Times to other voltages are:

Voltage	Time (hours)
1.2	3.8
1.1	6.8
1.0	10.0
0.9	12.5

For 10 ohms/cell, the times to different voltages are:

Voltage	Times (hours)
1.25	11.5
1.20	17.0
1.10	23.0
1.00	28.0
0.90	35.0

(3) ***Effect of intermittent discharge.*** Dry batteries have the property of recuperation. If a battery which has apparently been exhausted is allowed to stand on open circuit for a time, polarization products are consumed, the battery recuperates, and is capable of being further discharged. If we measure capacity by the total time of discharge through a specified ohms per cell to a specified end voltage, the capacity is greater for an intermittent discharge than for a continuous discharge. Figure 62-15 gives information on the greater capacity which can be obtained from a size F Leclanche cell by discharging it intermittently instead of continuously.

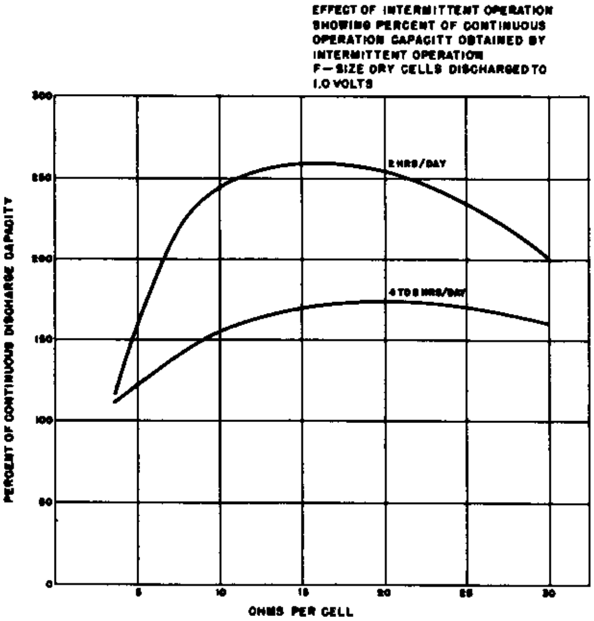

Figure 62-15. Effect of intermittent operation showing percent of continuous duty capacity obtained by intermittent operation.

(4) ***Effect of temperature.*** The capacity of a Leclanche dry battery, as measured by time of discharge through a specified ohms per cell to a specified end voltage, increases with the temperature. This is shown by figure 62-16 which is for a size F Leclanche cell discharged through 83.3 ohms to 1 volt.

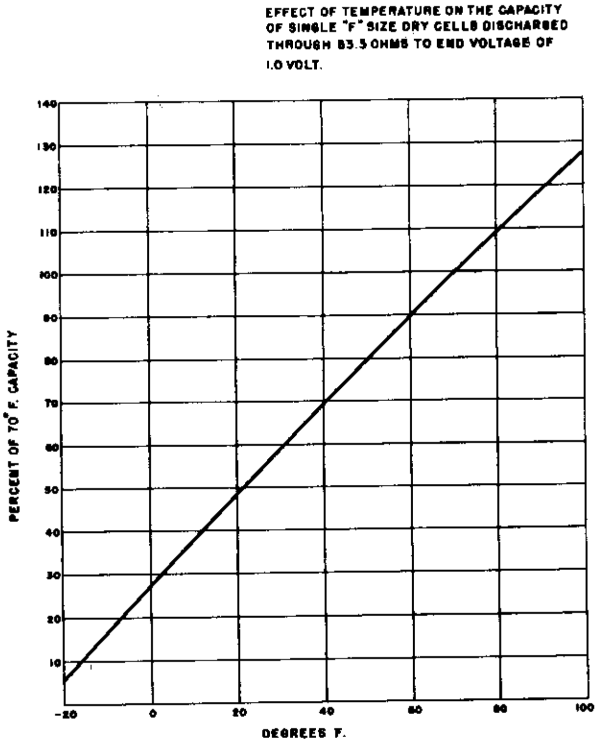

Figure 62-16. Effect of temperature on capacity of size F Leclonche cell discharged continuously through 83.3 ohms to a final voltage of 1.0 volt.

62-348. CHARACTERISTICS OF OTHER CELLS

Mercury and low temperature cells have superior characteristics for special applications but are not used as extensively as Leclanche cells because of their greater cost.

B. SHIPMENT AND STORAGE

62-361. UNIT PACKAGES

All batteries and materials used in their construction are carefully inspected by government inspectors to make sure they are in conformity with specifications. Specifications require batteries to be wrapped in small unit packages containing one or more batteries. The unit packages are wrapped in polyethylene plastic bags. ***The polyethylene bags on the unit packages should not be removed until the batteries are needed for actual use.*** This wrapping helps to protect the batteries from the detrimental action of outside temperature and humidity. The unit packages are packed in intermediate packages which are made of corrugated cardboard and are packed in wooden shipping containers.

62-362. PACKING OF 19026 BATTERIES

The Navy Type 19026 dry battery is the only exception to the packaging procedure. Because of its large size, it is always delivered to store activities packed in wooden boxes suitable for export shipment and should be kept in this packing box until issued for service.

62-363. STORAGE

Dry batteries are perishable. They deteriorate even when not in use, so that care should be exercised to provide storage conditions which will minimize deterioration. Where possible, dry batteries should be stored at temperatures equal to or less than 35° F in a room which is not dehumidified. Where refrigeration is not available, dry batteries should be stored in the coolest available space where they are not subjected to excessive dampness or large temperature fluctuations. Any battery taken from refrigerated storage should be allowed to warm up to between 65° F. and 80° F. before use in order to obtain maximum capacity.

62-364. SHELF LIFE

(1) *Definition.* The Navy defines shelf life as the length of storage time beyond which a group of batteries will contain so many dead batteries that the group is not considered fit for use. Shelf life depends not only upon the kind and size of a cell, but also upon the intended application. If a specific use requires that a high percentage of a battery's initial capacity be available and that the voltage drop on discharge be small, the shelf life assigned to a group of batteries intended for this application will be less than for a use which needs less capacity retention and can tolerate a greater voltage drop during discharge.

(2) *Effect of size on shelf life.* Batteries containing the smaller cell sizes do not retain capacity as well as those which contain the larger cell sizes. The following table gives the approximate percent of initial capacity retained after 1 and 2 years by several sizes of Leclanche cells. These figures are for batteries stored at room temperature. The table is arranged in order of increasing cell size from left to right and top to bottom.

Percent Initial Capacity Retained After Storage

Cell size	1 year	2 years
AA, A, B, C	70-80	50-60
D, F, 6	85-90	75

(3) *Shelf life tables.* Shelf life tables are issued by the various supply offices. Present shelf life tables are derived on the basis of general use requirements and will give a longer shelf life than may be tolerable for critical applications.

(4) *Test of individual batteries.* It should be clear from the definition of shelf life that the assignment of a certain shelf life to a given type of battery does not mean that each individual battery of this type will be good as long as it has not reached the end of its shelf life. It means only that in a group of these batteries a substantial percentage will be good so long as the end of the shelf life is not reached. The determination of whether an individual battery is usable or not can best be made by placing it in the equipment which it is supposed to operate and seeing whether it works or not. If this is not convenient, the battery can be tested by connecting it to a load equivalent to that of the equipment and measuring the closed circuit battery voltage. If this is above that required for satisfactory equipment operation, the battery is fit for use. No inference as to the hours of use left in the battery can

1 July 1967
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CHAPTER 9560

NAVAL SHIPS TECHNICAL MANUAL

Supersedes Chapter 9560 dated 1 July 1966

NAVSHIPS 0901-956-0000

Chapter 9560

Boiler Feedwater and Feedwater Apparatus

List of Effective Pages

PAGE NUMBERS	CHANGE IN EFFECT
1 – 56	Original

Original: 1 July 1967

NAVAL SHIPS TECHNICAL MANUAL
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NAVAL SHIPS TECHNICAL MANUAL
CHAPTER 9560 - BOILER FEEDWATER AND FEEDWATER APPARATUS

7/1/67

This printing supersedes Chapter 9560 dated 7/1/66 and includes all changes prior to this date.

CONTENTS

SECTION I. TREATMENT OF BOILER FEEDWATER AND BOILER WATER

Part 1 - Introduction

9560.1. PURPOSE OF SECTION I

This section presents water treatment in such a way that Naval personnel will be thoroughly familiar with it. A description of the shipboard water cycle is followed by the principles of boiler water and feedwater treatment, and a discussion and application of these principles to the treatment of Naval feedwater and boiler water. Also included in this section are illustrations and descriptions of the special apparatus and equipment needed in Naval vessels. Careful study of this chapter and compliance with its provisions should enable the ship's personnel to maintain the watersides of all boilers in practically new condition. The action required for any unusual condition not covered herein should be determined by the knowledge acquired from the study of this chapter. In any case of doubt or in cases not specifically covered in this chapter, the Ship Systems Command should be advised and instructions requested.

9560.2. PURPOSE OF BOILER WATER TREATMENT

Boiler water treatment prevents the formation of scale on the waterside of the boiler, reduces corrosion of boiler metal to a minimum, and ensures the absence of foaming under all conditions of operation. The careless application of water treatment chemical or blowdown, will result in unsatisfactory boiler protection.

9560.3 UNITS FOR REPORTING WATER ANALYSIS

The standard system for reporting the results of water analyses adopted by the Navy is in either **parts per million** (ppm) or **equivalents per million** (epm). Both are weight-per-weight units. Thus one part per million equals one unit weight of substance dissolved in one million unit weights of solution. One ppm may represent either one pound of salt dissolved in one million pounds of water, or one gram of salt dissolved in one million grams of water. Similarly, one equivalent per million equals one unit equivalent weight of substance per million unit weights of solution.

9560.4. TEST RECORDS-WATER TREATMENT LOGS

There are four types of water treatment logs. They are:

1. Feedwater log NAVSHIPS 9560/4 for feedwater
2. Boiler water treatment log- Navy boiler compound, NAVSHIPS 9560/1 for 600 psi boilers and below
3. Boiler water treatment log - Low phosphate treatment, NAVSHIPS 9560/3 for 1200 psi boilers
4. Boiler water treatment log - High phosphate treatment, NAVSHIPS 9560/2 for ships with diatomite feedwater filters.

Ships shall employ the feedwater log and the appropriate boiler water treatment log. Ships should prepare such additional test sheets as are necessary for entering results of other tests. Forms 9560/1 (FSN 0105-520-1000), 9560/2 (FSN 0105-520-2000), 9560/3 (FSN 0105-520-3000) and 9560/4 are available from Naval Supply Center, Norfolk and Oakland, in accordance with NAVSANDA Publication 2002, Section II.

Part 2 - Shipboard Water Cycle

9560.11. GENERAL

A familiarity with the shipboard water cycle will help personnel to understand the treatment of boiler feedwater and boiler water. Of basic importance is the fact that whether water is evaporated, diluted, or chemically treated, all shipboard water originally comes from the sea and therefore retains sea salts as the major contaminants. The shipboard water cycle in figure 9560-1 and its relation to the treatment of boiler feedwater and boiler water can best be understood by examining the feedwater phase, the boiler phase, and the steam condensate phase.

Sea water supplied to the shipboard cycle is a stable and uniform solution of about 35,000 parts per million (ppm) of mixed sea salts. The common components of sea water are listed in table I.

Table I

COMPONENT	PPM
Sodium Chloride ($NaCl$)	24,500
Magnesium Chloride ($MgCl_2$)	5,200
Sodium Sulfate (Na_2SO_4)	4,000
Calcium Chloride ($CaCl_2$)	1,100
Sodium Bicarbonate ($NaHCO_3$)	200
TOTAL	35,000

The calcium and magnesium are scale formers because they yield compounds of low solubility at high temperature and high pH (alkali content).

9560.12 MAKEUP BOILER FEEDWATER

Sea water enters the shipboard water cycle through a steamheated evaporator which evaporates one-third to one-half of the sea water to essentially salt-free vapor and sends the remainder overboard with the concentrated salts. The vapor is converted back into liquefied water (distillate) by passing it into the evaporator condenser where it flows over tubes filled with relatively cool sea water. From the

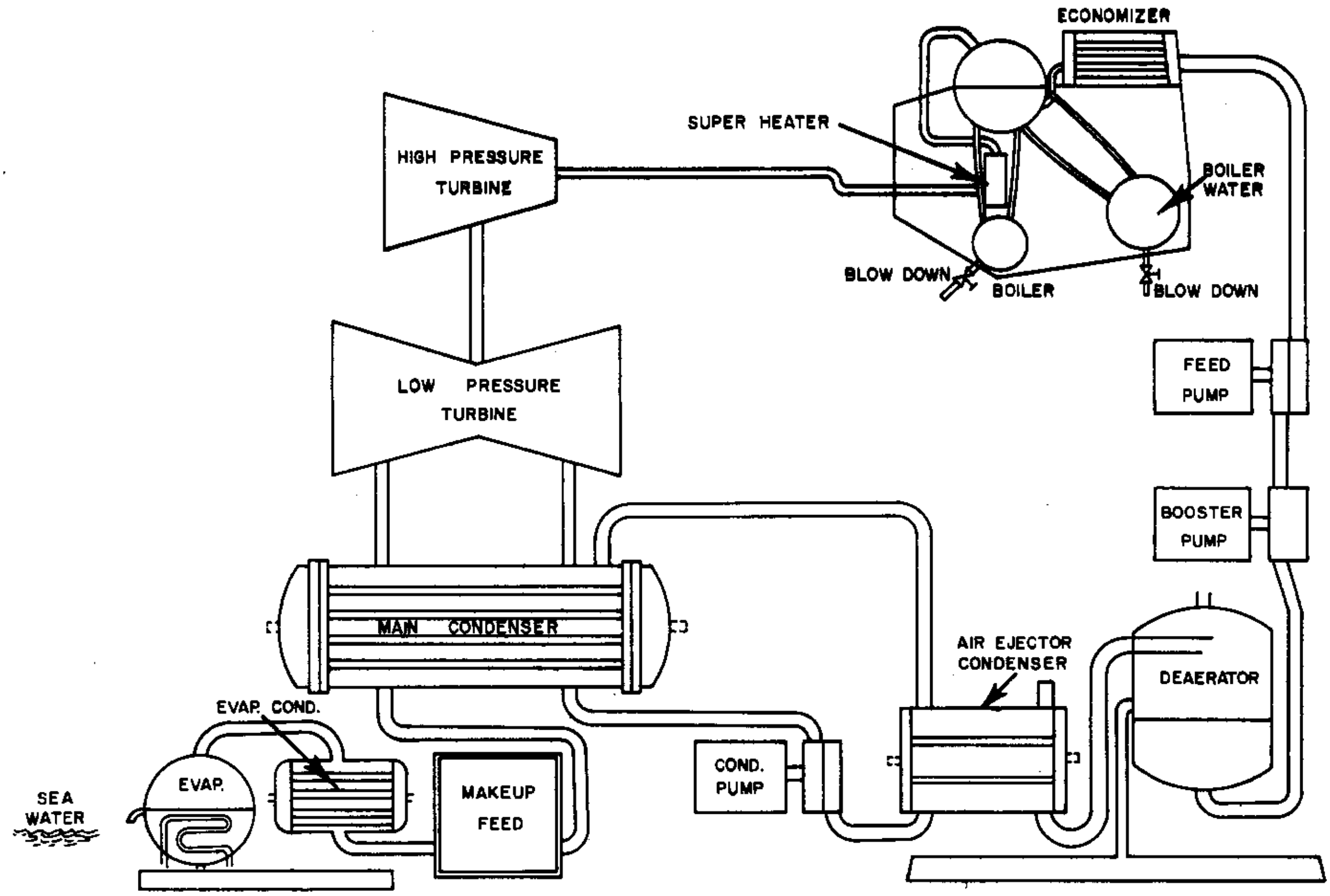

Figure 9560-1. Shipboard water cycle.

evaporator condenser, the distillate flows into the makeup feedwater tank. Actually the distillate is not pure water, but is diluted sea water containing about 1.75 ppm of sea salts.

9560.13. BOILER FEEDWATER

Boiler feedwater, the first component of the water cycle proper, combines makeup feedwater with steam condensate. Condensate is obtained from water which is boiled to steam in the boiler and is then reliquefied by contacting sea-water-cooled tubes in the main condenser. Boiler feedwater resembles makeup feedwater but may contain corrosion products from the steam lines and condensate lines, sea salts from the condenser tubes, dissolved solids and gases carried over from the boiler, and oil from fuel oil heaters.

Feedwater will usually contain from 1.7 to 3.5 ppm of dissolved solids of which sea salts are the major components. Poor quality feedwater may contain many times as much dissolved solids as the aforementioned quantity.

9560.14 DEAERATED BOILER FEEDWATER

Deaerated boiler feedwater is the same as the feedwater previously described except that most of the gases have been removed in the feedwater heater or deaerator either by heating the water or by heating it and then blowing steam through it. The dissolved solids content remains esentially the same as before the treatment.

9560.15. BOILER WATER

The boiler is an oil-heated pressure vessel designed to evaporate water to steam at an extremely high rate so that the steam can be used for operating machinery and heating. Reduced to the essential parts, the shipboard boiler consists of a large horizontal upper cylinder (steam drum), several horizontal lower cylinders (water drums and headers), and a number of small diameter (1-inch to 4-inch) nearly vertical tubes which connect the drums and surround the furnace fire.

When the furnace is lighted, heated water rises to the steam drum through the hotter fire-row tubes and returns to the water drum and headers via the more distant and therefore cooler tubes (downcomers). At the boiling temperature, steam collects in the upper part of the steam drum and increases in pressure to the operating pressure of the power plant. The steam at the operating pressure of the power plant is either passed through a nest of tubes exposed to the furnace gases (superheater) to increase its heat content (energy) or passed directly to the steam line as wet (saturated) steam, depending on the operating conditions.

The steam passes through the propulsion machinery, consisting of turbines or reciprocating engines, various pumps and auxiliaries. Eventually, the steam returns to the condenser where it recycles to the boiler.

Since the boiler does not have a continuous overboard drain, like the sea water evaporator, it traps or concentrates all types of solid matter introduced with the feedwater. This concentration alone is such a serious problem that personnel should always remember that no water is so pure that it will not eventually cause solid concentration in a boiler.

9560.16. STEAM AND CONDENSATE

Just as evaporator distillate is dilute sea water, so steam condensate is basically a mixture of dilute boiler water and dilute sea water. However, steam condensate usually has no more than 3.5 ppm of dissolved solids. Steam condensate may pick up salts from sea water leaks in the condenser and oil from fuel-oil heaters, and the returning of such water to the boiler can lead to serious waterside problems.

Part 3 - Principles of Boiler Water Treatment

9560.21. NEED FOR BOILER WATER TREATMENT

Boiler water treatment is necessary because some salts are dissolved in all waters. The salts dissolved in boiler water could include those derived from sea water by evaporator carryover and condenser leakage, those corroded from piping and tanks, those dissolved from filter media; from the coatings and interiors of piping and tanks, treatment chemicals and the various combinations that result from such mixtures. Some of these salts are corrosive, some are scale-forming, and some combat the objectionable properties of the first two classes. Any type of boiler-water treatment must be intelligently applied with a knowledge of the desired results and the methods of obtaining these results.

9560.22. PROCESS OF SCALE FORMATION

Salt scale is formed from the water directly in place on the heated metal part by crystallization processes induced by temperature changes. The solubility of salts in water varies with temperature of the water. Some salts are more soluble in cold water than in hot water (negative solubility), while the solubility of other salts increases as the temperature of the water increases. The salts that are more soluble in cold water (negatively soluble) form boiler scale. These negatively-soluble, scale-forming salts are relatively soluble in the cooler parts of the boiler, but in the boiler tubes, where the temperature is much higher, the saturation point may be reached although the actual concentration is low.

When a steam bubble is formed on the evaporative water surface, the salts in the water are forced into an envelope of water closely surrounding the bubble. Since salts do not evaporate, they remain in the water. Where the steam bubble, the water, and the tube surface touch each other, an irregular, circular-like line on the metal surface is formed. Crystals of scale-forming salts will be deposited on this line because it is the hottest point of the system. In this area, the solubility of the scale-forming salts will be the lowest and the quantity of these salts will be the highest. As the steam bubble leaves the metal surface, a ring of small scale crystals will be left to mark the location where the bubble was formed.

Because of their method of formation, scales have definite crystalline microstructures with crystals usually growing at right angles to the metal surface. Most scales are hard, dense and adherent, but some are soft and nonadherent. Figure 9560-2 shows the general appearance of typical scale. The method of formation and the resulting microstructure determine whether or not a deposit is scale. As previously mentioned, calcium and magnesium are the principal scale formers in the shipboard water system.

With the separation of successive steam bubbles, the many rings of scale crystals become interlaced and the indi-

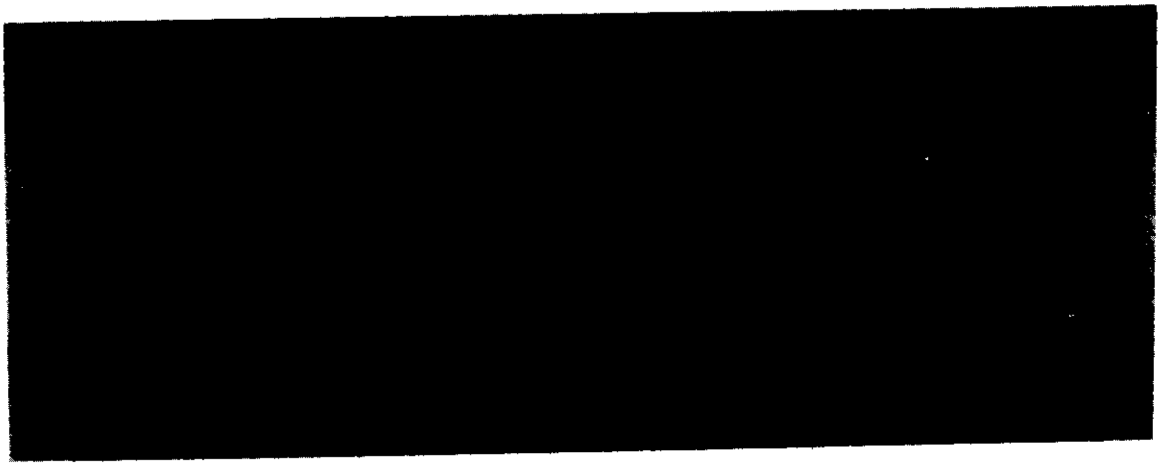

Figure 9560-2. General appearance of typical scale.

vidual crystals increase in size. This is the manner in which true scale grows. It is possible, however, under conditions to be discussed later, for suspended matter to settle from the boiler water and bake onto the evaporative surfaces. Although the effects of such deposits may be the same as scale, the deposits should be recognized as baked sludges, not scales.

9560.23. EFFECTS OF SCALE

A layer of scale on the waterside surface prevents normal heat transfer through the tube wall to the boiler water and thereby increases the temperature of the tube metal to the extent that wasting away from oxidation on the fireside and heat blistering and rupture from internal pressure may occur. A very thin layer of scale is sufficient to raise the tube-wall temperature enough to cause failure.

9560.24. SCALE-FORMING SALTS

Normally, calcium sulfate is the only scale-forming salt of serious importance in naval boilers. Calcium sulfate is soluble to the extent of over 1,500 ppm in boiler feedwater but is virtually insoluble at the temperatures existing in boiler tubes, so that in the absence of proper treatment, almost all of the calcium sulfate fed to the boilers will be deposited as scale. Calcium sulfate scale is so hard and tightly adherent that it is virtually impossible to remove it by mechanical cleaning. Silicates form hard, glass-like scales. Their occurrence usually is evidence of unusual feedwater conditions such as may be caused by the use of cement wash for coating feed bottoms, the use of shore water for makeup feedwater or the malfunctioning of oil-removal filters on ships equipped with reciprocating engines permitting the filter aid to enter the feedwater. Calcium carbonate and magnesium hydroxide occasionally occur in boiler scale but the solubility of these salts is so low at all temperatures that they are not of serious concern since they are a normal constituent of the boiler sludge. Properly prepared naval boiler feedwater is so pure and water treatment techniques are so effective that the occurrence of scale is very rare, and its presence should be the reason for a prompt investigation of the conditions which permitted its formation.

9560.25. PREVENTION OF BOILER SCALE

Boiler-scale prevention is relatively simple. It involves adding to the water one or more highly soluble chemicals, such as soda ash or caustic soda and sodium phosphate, which will react with scale-forming calcium sulfate to form highly soluble sodium sulfate and a relatively harmless sludge consisting of calcium phosphate. The reaction is:

Sodium phosphate + calcium sulphate=sodium sulphate + calcium phosphate.

When the ratio of hardness to alkalinity in the feedwater differs widely from that existing in sea water, as is the case when shore water is used, the completion of these reactions may yield intolerably high boiler-water alkalinities. It is always necessary to have an excess of the conditioning chemical present to insure that the chemical reactions will be complete. The presence of an excess also provides protection against any unexpected entry of scale-forming salts.

9560.26. BAKED SLUDGE

Sludges are sedimentary deposits of insoluble matter in the boiler water. Consequently, a certain amount of sludge is inevitable in every boiler because of the concentration phenomenon. Dirt, rust, insoluble products of evaporation or of water treatment, and oil all fall into this class. Since a sludge simply settles out or floats out of the water on the insides of tubes and drums, the deposit does not have a uniform microstructure, except stratification. Sludge may be a fine powdery mass or a conglomeration of many-sized particles. Most sludges originally are soft, or at least nonadherent, but they tend to become hard persistent deposits if allowed to remain on the boiler surfaces. Figure 9560-3 shows a typical sludge in a 2-inch boiler tube. Such sludges usually collect in the lower part of the boiler because they are heavy. They tend to concentrate and bake onto fire-row tubes because of the rapid evaporation at these points.

Heavy films of metal oxide or water-treatment sludges reduce heat transfer in water-wall and fire-row tubes to the extent that sludge baking and heat blistering