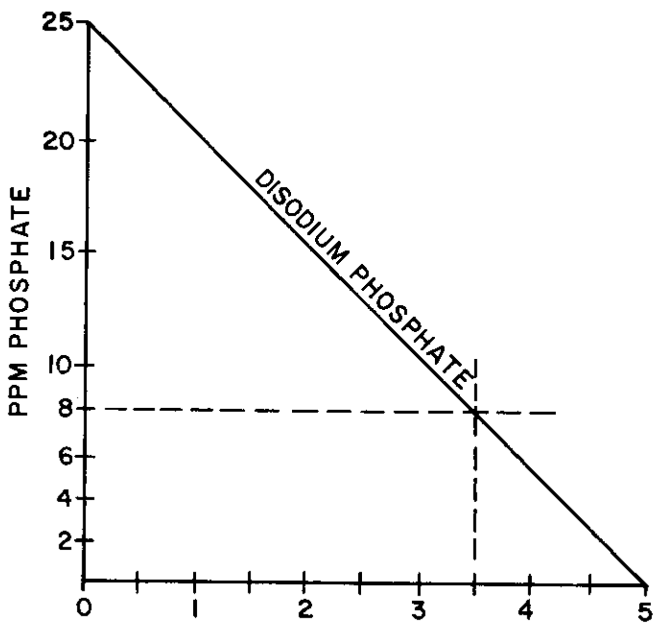

Figure 9650-14. Ounces of treatment per 1000 gallons to raise the pH value to 11.0.

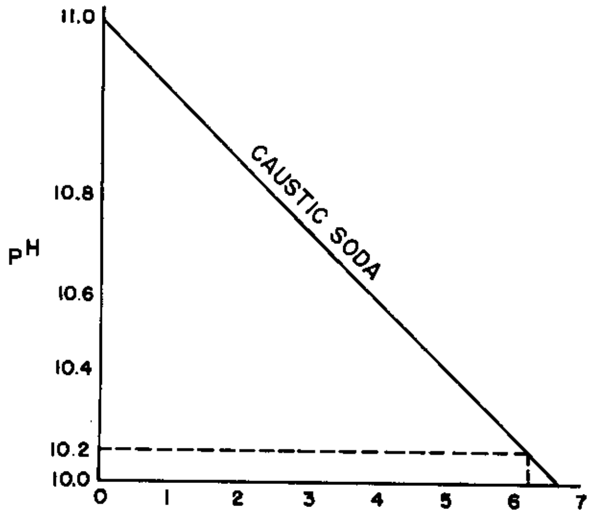

Figure 9560-15. Ounces of treatment per 1,000 gallons to raise phosphate content to 25 ppm.

2. Sample and test normal steaming boilers daily and after any water treatment (chemical addition or blowdown).

3. Sample and test idle boilers weekly, after any water treatment and prior to light-off.

4. In case of sea-water contamination or other instances of improper water conditions in steaming boilers, sample and test hourly, while adjusting conditions until they are within the specified limits.

9560.134. FREQUENCY OF BOILER FEEDWATER TESTS

The testing of boiler feedwater is the same as described in article 9560.77.

9560.135. BOILER WATER CONDITIONS TO BE MAINTAINED

Constituent or property:	Requirements
pH	10.4 to 11.0
Phosphate	10 to 25 ppm
Chloride	2 epm. max.
Conductivity	700 micromhos/ cm. max.

NOTE.—Soap hardness will be zero if the phosphate is in the range specified.

It should be pointed out that the chloride and conductivity values given above are maximum and not required values. In practice, it is possible to keep the pH and phosphate content of the boiler water within limits while maintaining the conductivity and chloride content of the boiler water well below maximum values. The best way to ensure that low dissolved solids are being carried in the boiler water is to maintain the chloride content as low as possible, preferably below 1 epm.

To ensure that an adequate phosphate reserve always is present in the boiler water, the phosphate content should be kept near the upper limit at all times. Wherever it is necessary to add treating chemicals to the boiler water, a sufficient quantity should be added to bring the constituents (pH or phosphate) to the upper limits. If the phosphate content of the boiler water drops below 10 ppm on two consecutive days, the boiler water should be sampled and tested at least once per watch until the source of contamination is located and corrected. Prior to securing a boiler for bottom blowdown, the boiler water should be chemically treated to bring conditions to a pH of 11.0 and a phosphate concentration of 25 ppm.

9560.136. FEEDWATER CONDITIONS TO BE MAINTAINED

The feedwater conditions to be maintained are the same as those described in articles 9560.91 and 9560.92.

9560.137. PREPARATION OF REAGENTS FROM STOCK SOLUTIONS

1. **Dilute stannous chloride reagent** (to be prepared daily). Remove the cap from the vial of concentrated stannous chloride and insert the 0.5 ml. pipette. Wash the empty vial with distilled water and measure into it 0.5 ml of the concentrated stannous chloride solution, using the 0.5 ml marked pipette. Fill the vial to the shoulder with distilled water and mix well by shaking the vial with its stopper in place.

CAUTION: Diluted stannous chloride reagent will deteriorate rapidly and will give erroneous results if it is not prepared daily. Discard the diluted solution when it is older than 24 hours or when it becomes turbid and prepare fresh reagent. The concentrated stannous chloride contains an acid so that it should be handled to prevent spilling on clothing or skin. Spilled reagent should be neutralized with sodium bicarbonate and flushed with water. The vials of dilute and concentrated stannous chloride should be kept stoppered. The pipettes should be replaced when the rubber bulb becomes brittle.

2. Instructions for preparation of other reagents required are given in articles 9560.78 through 9560.85.

9560.138 SAMPLING

The sampling instructions are the same as those described in articles 9560.94 through 9560.96.

9560.139. METHODS OF ANALYSIS—BOILER-WATER TESTS

1. General Test Procedures.

a. Boiler water is tested for pH value and phosphate content using the Taylor comparator kit. (The kit contains plastic components which are reasonably durable; however, they may warp or deteriorate if not properly cared for. Water or other liquids should not be allowed to stand on them nor should they be exposed to heat for prolonged periods. When liquids are spilled on the plastic components, they should be dried promptly.)

b. The chloride determination is made using the boiler water testing cabinet and test procedures described in article 9560.102.

c. Conductivity is determined with a Solu-Bridge, a commercial device manufactured by Industrial Instruments, Inc. Each Solu-Bridge is calibrated in such a way that it must be used with a conductivity cell of a definite cell constant. It is important to always remember that for accurate results, a Solu-Bridge can be used only with a cell of the correct constant. The cell contains two electrodes plated with platinum black, the surfaces of which should not be scraped or handled at any time. When the cell is not in use, it should be stored in distilled water.

2. pH Determination. This test is made using the Taylor pH slide comparator, pH range of 10.0 to 11.6 and acyl red indicator provided with the Taylor kit. The commercial Taylor pH slide comparator must be modified to make it suitable for use with Navy boiler water. Revise the pH scale on the comparator by adding 0.2 pH unit to each reading. (For example, the pH reading 10.0 should be revised to read 10.2. This should be done by completely obliterating the present value and durably inscribing the correct value directly on the comparator.) Also, the acyl red indicator deteriorates after being exposed to air for 6 months, therefore, it should be discarded 6 months after it is opened. The expiration date should be recorded directly on the bottle. The test procedure is as follows:

a. Carefully filter the water to be tested, using the folded filter paper and plastic funnel to remove all sludge, scale and other suspended solids which will interfere with the test. Sufficient water should be filtered to conduct both the pH and phosphate tests. Collect the filtered water in the graduated cylinder or a clean sample bottle.

b. Rinse three test tubes with a small portion of the filtered boiler water sample.

c. Then, fill three test tubes to the 5 ml. mark with the filtered water to be tested and place them in the holes back of the three slots in the base.

d. To the middle tube add 0.5 ml. of acyl red pH indicator solution by means of the 0.5 ml. pipette and nipple and mix thoroughly. The 0.5 ml. pipette (dropper) contains 0.5 ml. of solution when filled to the mark.

e. Place the acyl red pH slide on the base and the base on the shelf of the lamp. With the lamp switch on, move the slide in front of the test samples until a match is obtained. Read the pH directly from values on the slide. If, however, the color of the sample does not match either of two standards but lies between the colors of two consecutive standards, th pH is taken as the average of the two.

3. Phosphate Determination. This test is made using the Taylor low phosphate slide comparator, range from 0 to 25 ppm phosphate, according to the following instructions:

a. Wash one of the mixing tubes with the filtered sample to be tested (see pH Determination) and fill to the lower mark (10 ml.) of the tube. Carefully add molybdate reagent to the second mark (14 ml.), stopper, and mix well. Add exactly 1 ml. (twice volume contained in a pipette filled to the mark) of diluted stannous chloride solution, stopper, and again mix well. A blue color will form. Wait a full minute before comparing with the standard but complete the phosphate determination within the five minutes or the color will fade, making a color match difficult.

b. Rinse a 5 ml. test tube with a small amount of the blue solution.

c. Then fill the 5 ml. test tube with the blue solution and place it in the middle hole of the comparator base. Fill two other 5 ml. test tubes with the filtered, but untreated, boiler water and place them in the remaining holes back of the slots of the comparator base.

d. Place the phosphate slide on the base and place the base on the shelf of the lamp. With the lamp on, move the slide in front of the test samples until a color match is obtained. Be sure the arrow on the slide is directly in line with the arrow on the base. The phosphate value is then read off directly from the values on the slide. If the color does not match either of two standards but lies between them, the phosphate is taken as the average of the two.

e. If the color of the sample is darker than the darkest standard on the slide, repeat the test using a diluted solution consisting of one half filtered boiler water and one half distilled water. Multiply the comparator value by two to obtain the phosphate content of the original boiler water.

CAUTION: Molybdate reagent is a strong acid and should be handled like the stannous chloride reagent.

4. Conductivity Determination. Same as described in article 9560.104.

5. Chloride Determination. Same as described in article 9560.102.

9560.140. FEEDWATER TESTS

Same as described in articles 9560.105 through 9560.112.

9560.141. DETERIORATION OF CHEMICALS

The acyl red pH indicator and the concentrated stannous chloride solutions, used in the preceding tests, are subject to deterioration when repeatedly exposed to air and high temperature. For accurate test results, the containers of these chemicals should be closed immediately after use and stored in areas where temperatures are preferably below 80° F. but not above 100° F. After 6 months, the acyl red and concentrated stannous chloride solutions should be discarded in accordance with BUSANDA Manual 35041. To assist in determining when these two solutions have deteriorated, standards are available in the stock system. These standards and the respective stock numbers are given below:

Standards	Federal Stock Number
Class g - Standard low phosphate solution, 15 ppm phosphate	1H6810-985-7135
Class h - pH standard, buffer tablets or powders, pH - 10.8	1H6810-985-7128

Using the applicable standard, check the quality of the boiler water testing chemicals at least once every 3 months. The standards should be analyzed in accordance with the methods set forth in this chapter. The analytical results should be within the following limits:

Standard	Limits
Low phosphate (15 ppm)	10 - 20 ppm
pH 10.8*	10.8 - 11.2

* The standard pH solution should correspond to a value of 11.0 on the ships' corrected pH slides.

If the results obtained are not within the specified limits, fresh test chemicals should be used and checked against the appropriate standard. If the results still are not within specified limits, a shipyard chemist should be contacted at the earliest opportunity for assistance in locating the source of the error.

Other test chemicals should be checked for deterioration as stated in article 9560.99.

9560.142 BOILER WATER BLOWDOWN

Same as described in article 9560.118.

9560.143. TEST RECORDS – WATER TREATMENT LOGS FOR FEEDWATER AND FOR BOILER WATER OF 1200 PSI BOILERS

1. For Feedwater: Feedwater logs (NAVSHIPS 9560/4) are provided for feedwater.

2. For boiler water of 1200 psi boilers: Boiler water treatment Logs – Low phosphate treatment (NAVSHIPS 9560/3) are provided for boiler water tests of 1200 psi boilers.

Ships should prepare such additional test sheets as are necessary for entering the results of other tests. See article 9560.4 for availability of forms.

9560.144. STOCK INFORMATION

The disodium phosphate required, purchased under Federal Specification O-S-639, is available in the standard Navy stock system under FSN 6810-584-4298 in 25-pound drums. (This chemical is also known as dibasic sodium-phosphate, anhydrous, technical grade; or disodium mono-

W. A. Taylor Co. Boiler Water Slide Comparator Outfit for 1200 psi Ships	Taylor Catalog No.
1 – Complete Kit (Model P) (Contains all equipment for low phosphate determination, except Dalite Lamp)	1106
1 – pH color standard slide, Acyl Red, pH (10.0-11.6) (Contains pH slide comparator, vial of indicator solution and 0.5 ml pipette)	1000-P
1 – Midget Dalite Lamp	1070
Replacement Parts for above Kits:	
1 – Bulb, electric, special, 40W, 110V.	506
1 – Bottle, 16 oz., plastic, dispensing assembly	486A
1 – Test tube, 5 ml	500
1 – Vial, 2/3 oz. Reagent, empty, with 0.5 ml pipette	502A
1 – Filter paper, No. 5, 9.0 cm.	518
1 – Cleaner, sponge, 7" for mixing tube #516	529A
1 – Mixing tube, low phosphate	516
1 – Color standard, single (give actual slide value, name of slide or set)	503
1 – Dalite lamp glass filter	505
1 – Funnel, 50 mm, plastic	517
1 – Low phosphate slide only	1105B
Low Phosphate and pH Stock Solutions	**Federal Stock Number**
1 – Molybdate Reagent, 1 qt. Taylor Code No. 601	1HA-6810-903-0507
1 – Stannous Chloride Solution (concentrated), vial, 1/2 oz. Taylor Code No. 602	1H-6810-965-2320
1 – Acyl red indicator solution, vial, 1/2 oz. Taylor Code No. 1003P	1H-6810-965-2321

NOTE: The stannous chloride (concentrated) solution and the Acyl Red Indicator solution are forwarded quarterly to each ship requiring them for testing. This is done on an automatic basis by the supplier.

hydrogen phosphate, anhydrous, technical grade.) The caustic soda, also known as lye or sodium hydroxide, is purchased under Federal Specification O-S-598 and is available under FSN 6810-243-4435 in 13-ounce cans. Stock information on equipment required to conduct the pH and phosphate tests is given below.

Information on other chemicals and equipment required is given in article 9560.116.

Part 7 - Water Treatment-Ships with Diatomite Feedwater Filters

9560.151 REASON FOR SPECIAL INSTRUCTIONS

1. Ships equipped with diatomite feedwater filters (Republic, Skinner, Hercules or Davis) have different water conditions from other naval ships. In other ships, sea water is the only feedwater contaminant. Consequently, the feedwater is neutral or slightly acid and the chloride concentration is a good indication of the total dissolved solids being fed to the boilers. The uniform composition of the sea water contaminant makes it possible simultaneously to control hardness and alkalinity with Navy Boiler Compound. This is normally a uniform mixture of disodium phosphate, soda ash, and starch in proper proportions to counteract the effects of sea salts.

2. The filter aids used in the Diatomite filters on certain ships add hardness to the feedwater over and above that introduced as sea salts. If extra boiler compound is added to control this hardness, high boiler water alkalinity results.

9560.152. THEORY OF SPECIAL TREATMENT

The revised treatment overcomes this problem of extraordinary hardness by supplying separate treating chemicals rather than a mixture. They include caustic soda (lye) which increases alkalinity, disodium phosphate which reduces hardness without increasing alkalinity significantly, and corn starch which aids in conditioning of sludges. The caustic soda is added on the basis of the present alkalinity tests to keep the boiler water between 2.5-3.5 epm of alkalinity. The phosphate is added on the basis of a new colorimetric phosphate test as necessary to keep 20 to 100 ppm of phosphate in the boiler water at all times. Starch is added in proportion to the phosphate.

NOTE:—The following articles of this chapter do not apply to boilers treated in this manner.

9560.71. Nature of Boiler Compound
9560.72. Determination of Dosage
9560.73. Use of Charts
9560.74. Boiler Water Hardness
9560.87. Alkalinity and Hardness Limits

9560.153. CHEMICAL TREATMENT OF BOILER WATER

1. **Determination of dosage to a freshly filled boiler.**— The amounts of disodium phosphate, cornstarch, and caustic soda needed to raise the phosphate content and alkalinity approximately to the upper specified limits are shown in table V.

TABLE V
Treatment For Ships With Diatomite Feedwater Filters

Gallons Untreated Water Added	Phosphate-Starch Addition: Ounces Disodium Phosphate to be Added	Ounces Cornstarch to be Added	Ounces Caustic Soda to be Added
100	2	0.5	2
500	10	2.5	10
1000	20	5.0	20
1500	30	7.5	30
2000	40	10.0	40

2. **Determination of dosage to a steaming boiler.** Add disodium phosphate or caustic soda in increments as required to maintain the phosphate content and alkalinity within the specified ranges. A weight of starch equal to 1/4 the weight of phosphate is to be added with the phosphate. The amount of disodium phosphate needed to raise the phosphate content to 100 ppm may be estimated by use of figure 9560-16. The amount of starch needed can also be estimated from figure 9560-16. For example, to raise the phosphate content from 15 ppm to 100 ppm, draw a horizontal line from 15 ppm on the vertical scale. Draw vertical lines from the points where it intersects the starch and disodium phosphate lines. Read the amounts of starch and phosphate needed at the points where the vertical lines intersect the horizontal scale. In this example, about four and one quarter ounces of starch and 17 ounces of phosphate are needed for each 1,000 gallons of water in the boiler.

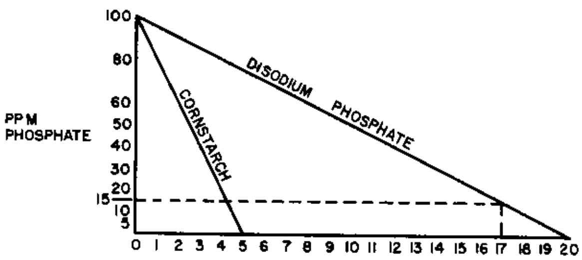

Figure 9560-16. Ounces of treatment per 1,000 gallons to raise phosphate to 100 ppm.

To determine the amount of caustic soda needed to maintain the alkalinity of the boiler water within limits, figure 9560-17 should be used. For example, to raise the alkalinity of the boiler water from 2.0 to 3.5, draw a horizontal line from 2.0 on the vertical scale. Draw a vertical line down from where it intersects the caustic soda line. Read the amount of caustic soda to be added at the point where the verical line intersects the horizontal scale. In this example, approximately eight and one-half ounces of caustic soda are needed for each 1000 gallons of water in the boiler.

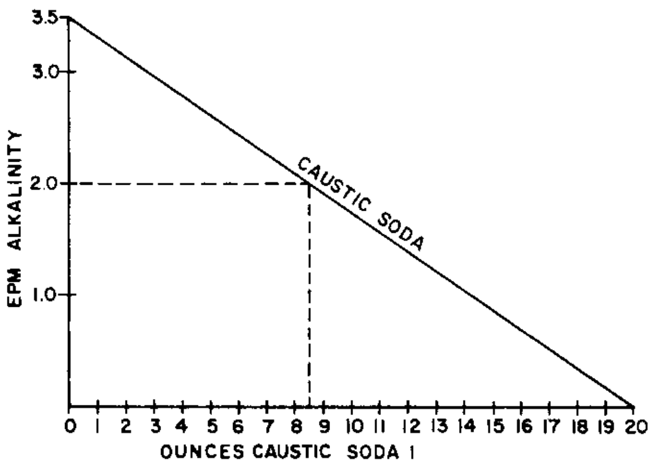

Figure 9560-17. Ounces of treatment per 1000 gallons to raise the alkalinity content to 3.5 epm.

3. Addition of chemicals to the boiler. Completely dissolve the phosphate in several gallons of hot water and then stir into it a cold-water paste of the starch. The paste is prepared by adding a small amount of water to the starch and mixing well until all the starch is wet. Feed the phosphate starch mixture to the boiler. Completely dissolve the caustic soda in several gallons of cold water.

CAUTION: Avoid contact of the caustic solution with skin or eyes. In case of contact, rinse quickly and thoroughly with cold water and report to sick-boy.

9560.154. FREQUENCY OF TESTS ON BOILER WATER

The boiler water will be sampled and tested for conductivity, phosphate, chloride, and alkalinity content in accordance with the procedures and schedule outlined in article 9560.133.

9560.155. FREQUENCY OF TESTS ON BOILER FEEDWATER

Same as described in article 9560.77.

9560.156. PREPARATION OF REAGENTS

1. Dilute stannous chloride reagent (to be prepared daily). Remove the cap from the vial of concentrated stannous chloride and insert the 0.5 ml. pipette. Wash the empty vial with distilled water and measure into it 0.5 ml. of the concentrated stannous chloride reagent, using the 0.5 ml. pipette. Fill the vial to the shoulders with distilled water amd mix well by shaking the vial with its stopper in place.

CAUTION: Diluted stannous chloride reagent will deteriorate rapidly and will give erroneous results if it is not prepared daily. Discard the diluted solution when older than 24 hours or when it become turbid, and prepare fresh reagent. The concentrated stannous chloride contains an acid and it should be handled so as to prevent spilling on clothing or skin. Spilled reagent should be neutralized with sodium bicarbonate and flushed with water. The vials of dilute concentrated stannous chloride should be stoppered. The pipettes should be replaced when the rubber bulb becomes brittle.

2. Instructions for the preparation of other reagents required are given in articles 9560.78 through 9560.85.

9560.157. BOILER WATER CONDITIONS TO BE MAINTAINED

Constituent or property:	Requirement
Phosphate	20 to 100 ppm.
Alkalinity, phenolphthalein	2.5 to 3.5 epm.
Chloride	2 epm max.
Conductivity	1300 micromhos/cm. max.

Note. Soap hardness will be zero if the phosphate is in the range specified.

Prior to securing a boiler for bottom blowdown, chemically treat the boiler water to bring the alkalinity to 3.5 epm and the phosphate concentration to 100 ppm. Prior to placing a replacement feedwater filter on the line, the phosphate concentration of the boiler water shall be at 100 ppm.

9560.158. FEEDWATER REQUIREMENTS

Same as described in articles 9560.91 and 9560.92.

9560.159. METHODS OF ANALYSIS FOR BOILER WATER TESTS

1. General test procedures. The boiler water will be tested for conductivity, chloride and alkalinity in accordance with the procedures in articles 9560.100, 9560.102 and 9560.104. The boiler water is tested for phosphate content using either the Taylor high phosphate comparator or LaMotte phosphate comparator.

2. Phosphate determination (Taylor-High-Phosphate 5.100 ppm Comparator).

a. Wash one of the mixing tubes with the clear boiler water to be tested (filter through filter paper if dirty) and fill to the lower mark (5 ml.) of the tube. Carefully add molybdate reagent to the second mark (15 ml.), stopper and mix well. Add stannous chloride solution to the top mark (17.5), stopper and again mix well. A blue color will form. Complete the following steps of the phosphate determination within the next 5 minutes or the color will fade, making a color match difficult.

b. Fill a 5 ml. test tube with the blue solution and place it in the middle hole of the comparator base. Fill two other 5 ml. test tubes with the clear filtered boiler water and place them in the remaining holes of the comparator base.

c. Place the phosphate slide on the base and place the base on the shelf of the lamp. With the lamp on, move the slide in front of the test samples until a color match is obtained. Be sure the arrow on the slide is directly in line with an arrow on the bone. The phosphate value is then read off directly from the values on the slide. If the color does not match either of two standards, but lies between them, the phosphate is taken as the average of the two.

d. If the color of the sample is darker than the darkest standard on the slide, repeat the test using a diluted solution consisting of one half filtered boiler water and one-half distilled water. Multiply the comparator value by two to obtain the phosphate content of the original boiler water.

CAUTION: Molybdate reagent is a strong acid and should be handled like the stannous chloride reagent.

3. Phosphate determination (LaMotte kit).

a. Rinse one of the marked test tubes with clear, filtered boiler water to be tested.

b. With the 1 ml. graduated dropper, add 1 ml. of the clear, filtered boiler water to the tube.

c. Add distilled water to the mark on the tube (10 ml.).

d. With the 0.5 ml. graduated dropper, add 0.5 ml. of reagent A (sulfuric acid).

CAUTION: Reagent A is a strong acid. If spilled on skin or clothing, rinse thoroughly, neutralize with baking soda or soda ash and reflush. Contact with eyes causes serious damage. Flush immediately with water and seek medical aid.

e. Add one tablet BC (molybdate and reducing agent).

f. Stopper tube and shake it until the tablet dissolves.

g. Place tube in middle hole of comparator next to the ground glass.

h. Place consecutive standard tubes (for example, 30 and 40 ppm) on either side.

i. View against a daylight lamp and change standards until phosphate value is found.

j. For phosphate concentrations above 100 ppm, test a mixture of half boiler water and half distilled water; multiply the readings by two.

9560.160. FEEDWATER TESTS

Same as described in articles 9560.105 through 9560.107.

9560.161. DETERIORATION OF CHEMICALS

The concentrated stannous chloride solution used in the phosphate test is subject to deterioration upon repeated exposure to air and high temperatures. For accurate test results, the stannous chloride container should be closed immediately after use and stored in areas where temperatures are preferably below 80° F. but not above 100° F. To determine whether this chemical is fit for use, the following standard solution should be used.

Standard	Federal Stock Number
Class f - Standard high phosphate solution, 50 ppm phosphate	1H6810-985-7134

Using the above standard, check the quality of the stannous chloride solution at least once every 3 months. The analytical results obtained should be within the following limits.

Standard	Limits
High Phosphate (50 ppm)	40 - 60 ppm

If the results are not within the specified limits, fresh test chemicals should be prepared and checked against the standard. If the results still are not within specified limits, a shipyard chemist should be contacted at the earliest opportunity for assistance in locating the source of the error. Other chemicals should be checked for deterioration as stated in article 9560.103.

9560.162. BOILER WATER BLOWDOWN

This is the same as described in article 9560.114.

9560.163. SAMPLING

This is the same as described in articles 9560.94 through 9560.95 or 9560.96.

9560.164. STOCK INFORMATION

a. Test Records - Water Treatment Logs for Feedwater and for Boiler Water of Ships with Diatomite Feedwater Filters.

1. For Feedwater: Feedwater logs (NAVSHIPS 9560/4) are provided for feedwater.

2. For Boiler Water of ships with diatomite feedwater filters: Boiler water treatment logs - High phosphate treatment (NAVSHIPS 9560/2) are provided for boiler water tests for ships with diatomite feedwater filters.

Ships should prepare such additional test sheets as are necessary for entering the results of other tests. (See article 9560.4 for availability of forms.)

b. Stock information. The disodium phosphate required, is purchased under Federal Specification O-S-639 and is available in the standard Navy stock system under FSN 6810-584-4298 in 25-pound drums. This chemical is also known as dibasic sodium-phosphate, anhydrous, technical grade; or disodium monohydrogen phosphate, anhydrous, technical grade. The required caustic soda, also known as lye or sodium hydroxide, is purchased under Federal Specification P-S-631, and is available under FSN 6810-243-4435 in 13-ounce cans. The cornstarch is available under FSN 6810-656-1041 in 5-pound boxes. Stock information on chemicals and equipment required to conduct the phosphate analysis is given below.

W. A. Taylor Co. Boiler Water Slide Comparator Outfit for Ships with Diatomite Filters

1 - Complete Kit (Model P) (Contains all equipment for high phosphate determination except Dalite lamp)	1101
1 - Midget Dalite lamp	1070

Replacement parts for foregoing kit are the same as under article 9560.144 except as follows:

1 - Mixing tube, high phosphate	515
1 - High phosphate slide only	1100B

High Phosphate Stock Solutions

1 - Stannous Chloride (concentrated) vial, 1/2 oz.	602
1 - Molybdate Reagent, 1 qt. Taylor Code 601	FSN 1HA-6810-903-0507

Information on other chemicals and equipment required is given in article 9560.116.

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

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SECTION II-FEED WATER SYSTEMS AND APPARATUS

PART 1-PURPOSE

9560.201. GENERAL

The design and arrangement of feed systems for naval vessels have undergone a series of major modifications since the original open feed system was established soon after the advent of condensers for recovery of boiler steam as condensate. During recent years this development has been particularly rapid in order to keep pace with the accelerated development of high-speed turbines, double reduction gears, superheat-control boilers with economizers, increased steam pressure and temperature, improved damage-control facilities, and associated changes in the machinery installed aboard naval vessels. For reasons made clear in articles 9560.30 and 9560.31 of section I, the elimination of dissolved oxygen has been a primary consideration throughout this development. The purpose of this section is to familiarize naval personnel with the various types of feedwater systems, together with their associated apparatus, in order that optimum operation may be attained in service.

9560.202. TYPES OF FEED SYSTEMS

There are four general types of feed systems installed aboard naval vessels: open, semienclosed, vacuum closed, and pressure closed. The simple open-feed system, installed in all steam-propelled naval vessels having relatively low main steam pressures, was replaced by the semienclosed feed system with the increase in steam pressure from 300 to 400 pounds per square inch. The next step in the development of feed systems entirely eliminated the free access of atmospheric air to the feed water by employment of a surge tank vented to condensers of the vacum-closed system. This was replaced by the pressure closed feed system as steam pressure was increased to 1200 p.s.i. with 950° F. steam temperature. In the following discussion of each of the type-feed systems, it should be recognized that there are many minor variations in each type, and discussion will be limited to a typical arrangement of each of the four basic types.

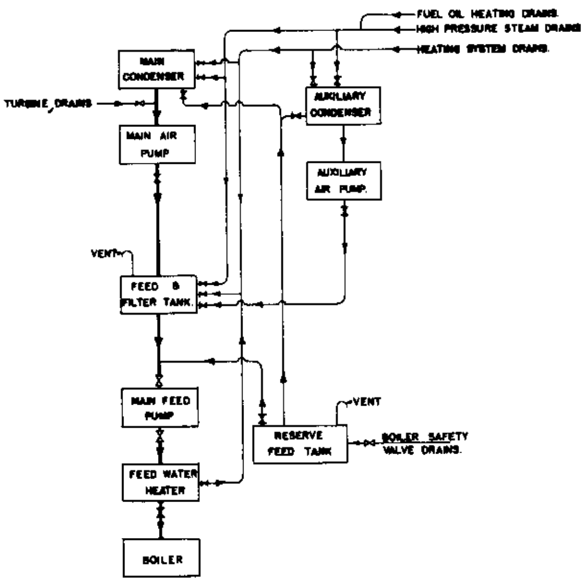
PART 2-OPEN FEED SYSTEM

9560.211. GENERAL ARRANGEMENT

The arrangement of the open feed system is indicated diagrammatically in figure 9560-6. Condensate from the main and auxiliary condensers is extracted by the air pumps and discharged directly to the feed and filter tank. The feed and filter tank normally receives drains from the feed heater(s), fuel-oil heaters, etc., and is vented to the atmosphere. The reciprocating main feed pump takes suction from the feed and filter tank and discharges through the feed heater(s) to the boilers. Make-up feed water is taken into the system through lines connecting the condensers with the reserve feed tanks.

9560.212. DISPOSAL OF DRAINS

Under conditions of operation when hot drains constitute a large part of the total condensate entering the feed and



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filter tank, the temperature of the contained feed water may approach the boiling point and cause excessive loss of feed water as vapor discharged through the feed and filter tank vent. A more serious consequence of excessive feed and filter tank temperature is the possibility of vapor binding of the main feed pump in installations where the feed pump is not located adjacent to and well below the feed and filter tank. Provision is made for discharging hot drains to the condensers, when necessary, to avoid excessive feed and filter tank temperatures. Heating-system drains are properly discharged to the feed-water heater shell, as an economic measure, unless the heat contained in these drains can be effectively used to raise the temperature of the water in the feed and filter tank. The discharge of hot drains to a condenser under vacuum is uneconomical as the drains are cooled to the temperature corresponding to the condenser vacuum through "flashing," the flash steam being condensed by the condensing surface and its heat lost to the circulating water. The discharge of hot drains to condensers should be avoided unless necessary to secure proper drainage or to control maximum feed and filter tank temperature.

9560.213. AIR PUMP

The reciprocating wet air pumps of the open feed system are responsible for relatively high oxygen content of the feed water. On the beginning of each stroke, condensate is drawn through the foot valves of the pump first, followed by the air which at the usual condenser vacuum represents by far the largest part of the cylinder displacement. This air has to pass through the condensate drawn into the bottom of the cylinder at the beginning of the suction stroke. On the down stroke the air passes through the piston valves first, followed by the condensate. On the up stroke the air is discharged through the discharge valves first, followed by the condensate. The delivery side of the discharge valves is subject to the head of the feed tank, which is generally located well above the air pump. The air, therefore, passes again through the condensate in the pump discharge line and escapes through the feed-tank vent. The second passage of the air through the condensate is effected at a pressure somewhat above atmospheric and the relatively cold condensate is capable of absorbing large quantities of oxygen, as may be seen by reference to figure 9560-1. Assuming, for example, that the condenser vacuum is 28" Hq and the condensate temperature is 90° F., it may be observed from figure 9560-1 that a maximum of about 0.15 p.p.m. of oxygen can be absorbed by the water. If the 90° F. condensate in the air-pump discharge line is at atmospheric pressure, figure 9560-1 shows that the water is capable of absorbing over 7.3 p.p.m. of oxygen from the air bubbling through the water on the discharge stroke of the pump, or almost 50 times as much oxygen as it contained in the condenser hot well. Unfortunately, the reciprocating air pump constitutes an effective aerator.

9560.214. FEED AND FILTER TANK

As noted above, the air pumps discharge to the feed and filter tank which serves as a reservoir for condensate and miscellaneous drains from the various machinery units throughout the engineering establishment. These tanks are usually divided into two compartments, separated by a horizontal plate. The upper part is known as the filter tank and contains filtering material for use in removing dirt and oil from the boiler's feed water. The tank is provided with an overflow either to the bilge or to the reserve feed tanks Vents to the atmosphere also are installed. The condensate enters the filtering compartment and thence overflows into the bottom of the tank, this overflow usually being enclosed and led to a point below the normal water level carried within the tank.

9560.215. FILTERING MATERIAL

Loofa sponges constitute a satisfactory filtering material where water temperature does not exceed 200° F. New developments in filtering material allow the use of synthetic or manufactured materials which are equally as efficient as loofa sponges and do not deteriorate so rapidly even at temperatures which decompose loofa sponges. It is important that the filtering material be secured in the filter compartment in such a manner as to prevent its getting adrift.

9560.216. INSPECTION AND CLEANING OF FEED AND FILTER TANK

Feed and filter tanks should be inspected and cleaned at least quarterly. More frequent cleaning may be required if the vessel does more than normal steaming. In the event of abnormal leakage of oil into the system, the source of the leakage should be corrected and the feed and filter tank cleaned using the chemicals and a similar proceedure as outlined in chapter 9510.87.13. Care must be exercised as to the temperature and pressures at which the cleaning procedure is carried out, in that the design pressure criteria of the feed tank is not exceeded. The filtering material should be inspected frequently for signs of grease or deterioration. This material is relatively cheap and frequent renewals are desirable. The strainers fitted over the feed pump suction connections to the tank should be inspected carefully for fouling. When renewing the strainer plates, it is important that the size and number of holes in the plate be made the same as the original design. The combined area of the holes in the plate should be 50 percent greater than the area of the pipe connection which it serves.

9560.217. FEED TANK TEMPERATURE

It is important that the feed tank temperature be kept as high as practicable as noted in article 9560.212 in order to obtain the maximum economy and also to assist in the removal of dissolved and entrained air entering the tank with the incoming water. The higher the temperature the less air will remain dissolved in the water. Carrying forward the example discussed in article 9560.213, incoming condensate at 90° F. containing 7.3 ppm. of dissolved oxygen can retain in solution only 1.2 ppm. at a feed-tank temperature of 200° F. Thus more than 6 ppm. of the dissolved oxygen in the incoming condensate will tend to be released from the feed water, although an appreciable proportion of the released gas bubbles will be unable to escape from the water mass and will be carried along with the feed water to the boiler. The water should be as hot as can be handled safely by the feed pumps, but should not be permitted to boil, as the resultant waste of water by vaporizing in the tank and escaping through the vent pipe is excessive. The exact temperature must be determined for each installation and depends mainly upon the location of tank with relation to the feed pumps. Too high a temperature is frequently due to open drains or bypasses or to steam blowing through faulty traps. Thermometers are fitted for determining the feed tank temperature, and these thermometers always should be kept in place and in good condition.

9560.218. WATER LEVEL IN FEED TANKS

The designed volume of the feed and filter tank provides a reasonable amount of storage capacity in the system. It is desirable that the level in the tank never be allowed to fall below the normal working level under steady steaming conditions. This level should be marked plainly on the tank adjacent to the gage glass. In addition a higher level should be set and the tank filled to this level when taking make-up feed.

9560.219. FEED WATER HEATER

The water from the feed and filter tank of the open feed system is discharged by the boiler feed pumps through the feed water heaters to the boiler. These high pressure heaters are subject to boiler-feed pressure on the water side. The primary function of a feed heater is to raise the temperature of the boiler feed water before it reaches the boiler by the use of exhaust steam. This heating is usually accomplished by passing the feed water through tubes contained in a closed shell while admitting exhaust steam to the shell around the tubes. The useful heat in the auxiliary exhaust steam is properly utilized in the feed heaters, the distilling plant, and (if turbines are fitted for its admission) in lower pressure stages of main propelling machinery. Any excess auxiliary exhaust steam is routed to the condensers and constitutes an absolute heat loss, since it goes overboard in the form of heated circulating water.

9560.220. AIR CHAMBERS

Many feed water heater installations are fitted with an air chamber provided with a gage glass connected at the heated-water discharge. Other installations provide air cocks to vent the top of the discharge water chest of the heater, and in many cases the discharge from this air cock is led back to the feed tank. If under steady steaming conditions either of these devices installed in connection with high-pressure feed heaters shows any appreciable tendency for air to be separated from the feed water, this is evidence that the water in the feed and filter tanks is not being kept at a reasonably high temperature and that excessive quantities of dissolved oxygen are being discharged into the boilers with the feed water. In this case appropriate measures should be taken immediately to increase the feed and filter tank temperature by rerouting drains.

9560.221. TYPES OF HIGH-PRESSURE HEATERS

There are 3 types of high-pressure feed water heaters in service aboard various naval vessels provided with the open feed system:

1. **Straight tube types.**-These have straight tubes expanded into tube sheets and arranged to be either single pass or multiple pass, depending on the number of times the water is passed through the tubes. Expansion is taken care of by an expansion ring in the shell or by employing a floating head construction and the heater is so installed that one end is free to move.
2. **U-tube type.**-These are similar to straight tube heaters, except only one tube sheet is provided and the tubes are in the form of a U.
3. **Multicoil type.**-These have spiral coils of tubing, each end of the tube secured to a header or manifold by means of ground joint unions. Care must be taken that the coils do not rub against each other or against the shell of the heater, as pitting of the tubes will occur in service at the points of contact.

9560.222. TIGHTNESS OF HEATERS

With the U-tube and straight-tube types of heaters, difficulty is sometimes experienced in maintaining tight water-chest joints. Hence, to prevent loss of feed water, care must be taken that the water-chest gasket seatings are always kept in excellent condition and that the gaskets are made of the best grade of high-pressure sheet packing. Bolts and nuts give better results than studs when making up the heavy flange header joints.

9560.223. ECONOMICAL USE OF EXHAUST STEAM

When using exhaust steam to heat feed water, it has been found, both in theoretical calculations and in practical tests, that for every rise of about 10° F. in temperature of feed water there is a 1-percent reduction in the amount of heat necessary to produce the steam, with a corresponding reduction in fuel used.

9560.224. GENERAL FEATURES OF OPERATION

The temperature of feed water leaving the heater should be within 10° F. of that of the exhaust steam when steaming at normal speeds with a properly designed heater which is clean and in proper condition. The temperature of steam at 10 p.s.i. is 240° F. Hence, when steam under the best conditions, with p.s.i. back pressure, the feed water should leave the heater at about 230° F. Under all circumstances the feed water should be kept as hot as possible, the exact pressure at which to carry the exhaust steam being left to the discretion of the engineer officer, who should determine the point of maximum efficiency. In accomplishing this he must remember that all auxiliary machinery must work against the back pressure and that the back pressure should never exceed 15 psi when operating noncondensing turbine driven auxiliaries. The engineer officer must determine by experiment whether it is more economical to increase the pressure a few pounds or to operate with water at a slighty lower temperature. Usually it will be found more economical to carry the higher back pressure.

9560.225. WATER SEAL IN HEATERS

Under ordinary cruising conditions a water seal should always be maintained on the steam side of the heater. This can be done by keeping water in sight in the gage glass on the feed heater shell or in the gage glass of the feed heater drainer, if installed. However, water should never be allowed to build up in the shell of the feed heater as this reduces the effective heating surface, thus decreasing the heating capacity of the unit. Furthermore, flooding of the lower tubes during operation might also result, in extreme cases, in loose tube joints or broken tubes, because of the difference in temperature between those tubes surrounded by steam and those surrounded by condensate, aside from increasing corrosion difficulties.

9560.226. BAFFLES

Where baffles are fitted in feed-water heaters, they must be examined at the time of a regular overhaul of the heater, or in case the heater fails to function properly. If leakage exists past the water chest baffles which direct the flow of the water through various groups of tubes of multipass feed heaters, a quantity of the water goes directly through the heater, having bypassed many of the tubes, causing a drop in the feed water temperature. If the baffles installed in the steam space are improperly fitted or leak badly, circulation of the heating steam is impaired, causing a loss in efficiency and ineffective venting. Baffles should be fitted to prevent violent impact of drains entering the heater shell against the tubes. If these baffles are not kept in good condition, the tubes will be rapidly eroded and tube leaks will occur.

9560.227. VENTING

Air vents are properly provided on steam side and water side of feed-water heaters. The water side should be throughly vented when the heater is put in service and the vent cocks should be opened occasionally when steaming to assure that there is no accumulation of air. The steam side vents should be opened wide when warming up the heater and should also be occasionally opened during operation to prevent accumulation of air in the feed heater shell. Failure to vent properly will result in poor steam distribution and loss in effectiveness of the heating surface.

9560.228. TUBE LEAKS

If the drain discharge from the heater becomes excessive, a leaky tube is indicated. Tube leaks may be discovered by completely draining the shell, then shutting all valves in lines connected to the heater shell and continuing to circulate water through the tubes. If any of the tubes or tube joints are leaking, water will soon appear in the water gage. In order to determine which tube or tube joints are leaking, it is necessary to drain the tube bundle completely, remove both heads, and apply hydrostatic test to the shell. Water will flow out of one or both ends of any defective tubes or around any tube joints that may be leaking. The leak should be repaired by plugging both ends of the tube, or by replacing the defective tube with a new one or in case of a leaky joint, by expanding it. A tube expander and tube plugs are furnished with each installation.

9560.229. RELIEF VALVES

A relief valve should be installed on the shell of all feed-water heaters and a sentinel relief valve should be installed on one of the water chests. Most feed heater shells are provided with a 2-inch relief valve set at 20 to 25 pounds per sq. in. gage. The sentinel valve installed on the water chest should be set at one and one-half times the maximum working pressure and need be no larger than one-half inch as its major function is to protect the water side of the heater against excessive pressure due to expansion of the water should steam be admitted to the shell inadvertently when the water inlet and outlet valves are secured. When the feed heater is overhauled, the relief valves should be examined, overhauled if necessary, and reset to lift at the designed pressure. These relief valves should be tested whenever there is reason to believe that they are improperly set or not in proper working order.

9560.230. TESTS

Feed-water heaters should be given a hydrostatic test on the steam side to one and one-half times the maximum working pressure.

9560.231. CLEANING HEATERS

All feed heaters should be boiled out with a solution of trisodium phosphate at regular intervals, as described in chapter 9510.87.13. The actual hook-up to be devised by the ship to best fit the installation and to accomplish the purpose intended. The length of time between cleanings depends upon the condition of the plant, the purity of feed water used, and the amount of steaming done. Feed heaters installed in connection with turbine installations will ordinarily remain clean for much longer periods than when the vessel is powered with reciprocating engines. However, if trouble is experienced in heating feed water properly with moderate back pressure, the heaters should be examined and immediately cleaned if found coated on either the steam or water side of the heating surfaces with oil or grease or other foreign matter. Cleaning is best accomplished by using the same solution of boiler compound as is used for boiling-out boilers, heating it to the boiling point and circulating the mixture through the heater at as high velocity as possible, preferably by a small pump specially provided for the purpose. Cleaning may be accomplished by using a solution of 5 pounds of boiler compound per hundred gallons of water, heating it to the boiling point, and circulating the mixture through the heater at a high velocity as possible, preferably by a small pump especially provided for the purpose.

9560.232. GREASE EXTRACTORS

The filtering material in grease extractors, usually installed in vessels having reciprocating main engines, should be kept clean at all times. Careful attention should be paid to the pressure gage, and should the pressure on the discharge side of the extractor decrease to 10 pounds below that on the inlet side, the filtering material should be taken out and cleaned or renewed. Spare cartridges for grease extractors, with clean or cleaned filtering material, should be ready at all times and renewals made one or more times a day while steaming. Grease extractors usually are not installed on ships with turbine-driven machinery.

9560.233. SUMMARY OF IMPORTANT OPERATING REQUIREMENTS

1. Inspect and clean feed-tank filter frequently (article 9560.216).
2. Maintain feed-tank temperature as high as practical (article 9560.217).
3. Clean feed heaters at regular intervals (article 9560.231).
4. Feed heater and relief valves should be tested to one and one-half times maximum working pressure after overhaul or repairs (article 9560.230).
5. Take make-up feed water through condenser (article 9560.211).

PART 3-Semienclosed Feed System

9560.241. GENERAL

The open feed system discussed in part 2 was superseded by the semienclosed feed system during the period when the main steam pressure for new naval vessels was elevated from 300 to 400 psi gage. The higher steam pressure with associated higher temperature of feed water in boiler feed lines, economizers, boilers, and in main steam lines and high pressure turbines dictated the use of a type of feed system capable of reducing the oxygen content of the feed water far below that obtainable with the open condensate system. Development of the semienclosed feed system once initiated was rapid, and with each new class of naval vessels improvements in deaeration and thermal efficiency of the system were effected. Figure 9560-7 shows diagrammatically the elements of the semienclosed feed system in one of its final stages of development.

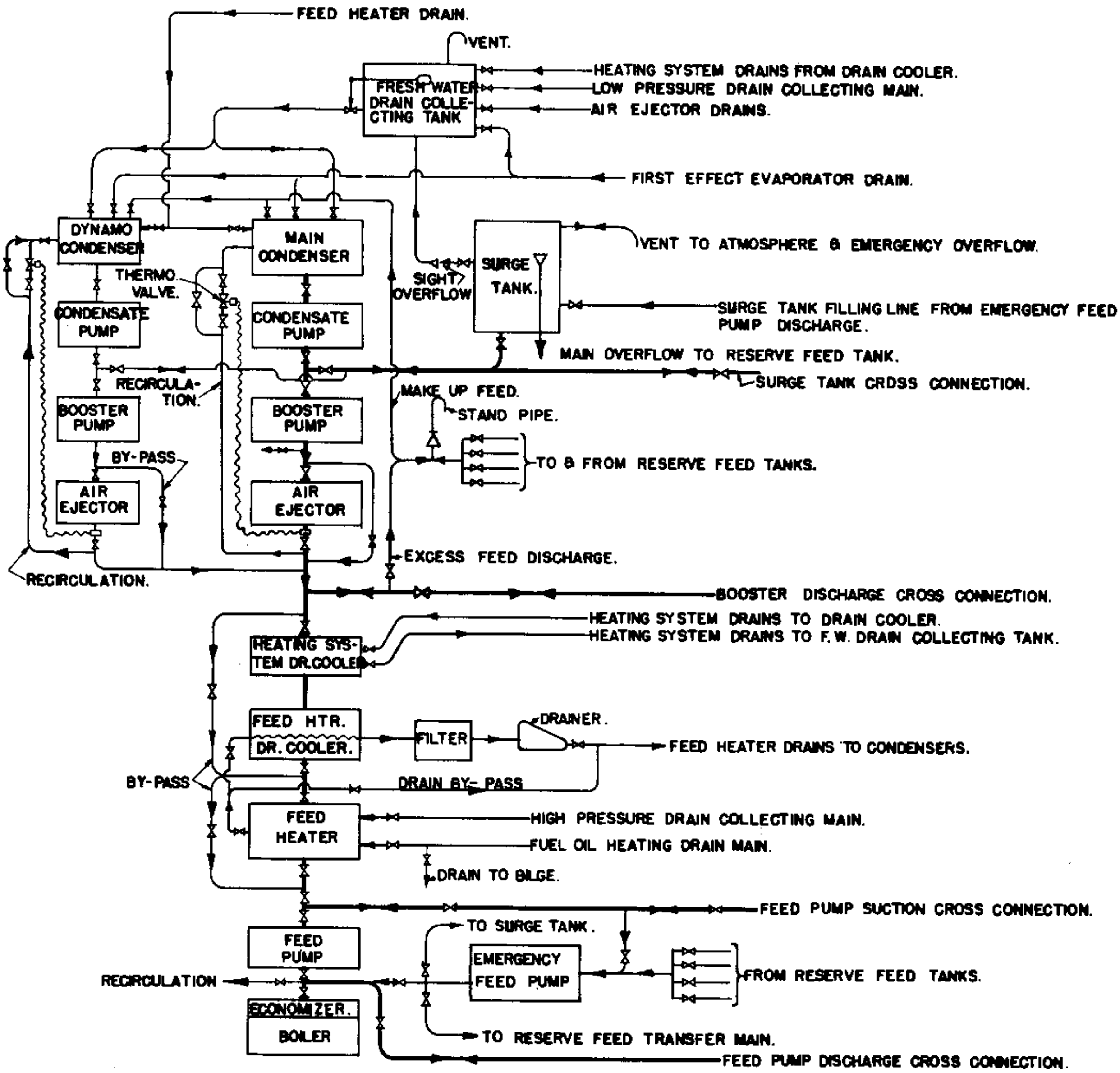


Figure 9560-7

9560.242. OPEN VS. SEMIENCLOSED SYSTEMS

The basic differences between the open feed system and the semienclosed system are made possible by the employment of centrifugal condensate pumps and air ejectors to replace reciprocating wet air pumps. This eliminates the aerating action described in article 9560.213 and avoids the necessity of passing all condensate through a feed and filter tank. Thus the elevated surge tank of the semienclosed system replaces the feed and filter tank of the open feed system and merely "floats" on the main condensate line, absorbing the excesses and supplying the deficiencies in the feed-water quantity which occur during maneuvering the vessel or changing speed rapidly. Sufficient volume is provided in the surge tank to avoid continual removal of excess feed or taking on make-up feed under conditions of rapidly changing load due to changes in the quantity of water in the boilers with decreases or increases in ebullition.

9560.243. FEED BOOSTER PUMP

In figure 9560-7 the flow of main condensation from the main condenser to the boiler is indicated by a heavy line, the various auxiliary condensate and drain lines being indicated by light lines. Condensate is withdrawn from the main and turbo-generator condensers by the condensate pumps which discharge to the feed booster pump suctions. In many installations the booster pumps are omitted and the condensate pumps discharge directly through the air ejector inter and after condensers, in which case the feed heater must be located beyond the main feed pump in the feed system in order to avoid vapor binding of the main feed pumps, and the surge tank is connected to the main condensate line directly ahead of the feed-pump suction instead of at the condensate-pump discharge as indicated in figure 9560-8.

9560.244. FEED HEATERS

Employment of the feed booster pump provides ample head on the main feed-pump suctions, permitting installation of the low-pressure feed heater ahead of the feed pump in lieu of a high-pressure heater beyond the pump, thus eliminating the necessity for designing the feed heaters to withstand main feed pressure. The feed heaters of the semi-enclosed feed system are otherwise similar to the straight or U-tube feed heaters described in section II, part 2, for the open feed system and perform the same economic function in heating the feed water by use of steam that has already expended part of its useful energy in the auxiliary or main turbines. Instructions contained in part 2 as to cleaning, venting, and upkeep of feed heaters are generally applicable to the feed heaters and drain coolers of the semi-enclosed feed system.

9560.245. DRAIN DISPOSAL

Semienclosed feed systems of the later types, as indicated in figure 9560-7, are provided with a heating system drain cooler and a feed heater drain cooler located in the main condensate line ahead of the feed water heater. These heat exchangers are heat recovery units and their provision improves the thermodynamic efficiency of the cycle. A large part of the useful heat available in the feed heater drains is transferred to the main condensate in the feed heater drain cooler. The cooled drains pass through a filter and an automatic drainer to the condensers. In systems not provided with the feed heater drain cooler, a drain pump is usually installed to pump feed heater drains to the main feed line beyond the air ejectors through a drain distributor. Use of this pump conserves the heat in the drains, but is undesirable, as drains are not deaerated prior to discharge to the boilers, as is the case when these drains are routed to the fresh water drain collecting tank or to condensers.

9560.246. FRESH WATER DRAIN COLLECTING TANK

The useful heat contained in the heating system drains is removed in the heating system drain cooler and the cooled drains are discharged to the fresh water drain collecting tank. As indicated in figure 9560-7 the fresh water drain collecting tank receives, in addition to cooled heating-system drains, other low-pressure drains including air-ejector drains, first-effect evaporator tube-nest drains, and the discharge of the low-pressure drain main, which normally collects various drains throughout the system, including open-funnel drains from auxiliary exhaust lines, auxiliary turbines, escape piping, safety valves, etc. These combined drains are discharged to the condensers via the float-controlled drain-tank discharge valve.

9560.247. HIGH-PRESSURE DRAINS

Fuel-oil heater drains, including high-pressure drains from fuel-oil heaters, heating coils in fuel-oil storage and settling tanks, and lubricating-oil settling and sump tanks, are collected in the fuel-oil heating drain main and are discharged along with drains collected in the high-pressure drain collecting main, including high-pressure drains from throttles, pockets in main and auxiliary steam lines, steam separators in saturated steam lines, etc., to the feed-heater shell instead of to the fresh water drain collecting tank in order to conserve useful heat contained in these drains. The high-pressure drains combine with the normal feed-heater drains and discharge through the feed-heater drain cooler to the condensers via the fresh water drain collecting tank as noted above.

9560.248. MAINTENANCE OF DRAIN ACCESSORIES

It will be noted that all machinery drains associated with the semienclosed feed system are led directly or indirectly to the main and turbo-generator condensers, thus providing for reasonable deaeration. Deaeration of machinery drains is accomplished in this manner without undue loss in thermodynamic efficiency through provision of the feed heater drain cooler and the heating-system drain cooler. Condensate bypasses are provided around these heat exchangers for use in the event of derangement of the units. These bypasses should normally be kept closed to avoid thermodynamic losses. Provision is made for bypassing feed heater drains around the feed heater drain cooler, filter, and automatic drainer for use in the event of derangement or when it becomes necessary to clean the filter. Instructions outlined in articles 9560.215 and 9560.216 for cleaning filters of the open-feed system are generally applicable to this filter.

9560.249. SURGE TANK

The arrangement of the semienclosed feed system, as indicated in figure 9560-7, prevents free access of atmospheric air to the main feed system at all points except in the surge tank which is vented to the atmosphere. Under steady steaming conditions at any power, contamination of the feed water with oxygen absorbed in the surge tank is minimized through provision of a small external sight overflow at the operating level. This open-funnel drain discharges to the fresh-water drain collecting tank, and when steaming steadily there should always be a slight quantity of feed discharge at this point. Under this condition, even though the feed water stored in surge tank reservoir becomes thoroughly saturated with oxygen, very little of the contaminated water finds its way to the booster pump suction because of the induced flow through the line connecting the surge tank with the main condensate line due to the sight flow discharge.

9560.250. MAKE-UP AND EXCESS FEED

Under maneuvering conditions when the level in the surge tank fluctuates with rapid changes in power, the main surge-tank overflow and vent lines take care of positive surges in the tank and the negative surges introduce oxygen-laden water into the boiler feed system. When the surge-tank level falls below the maneuvering low level, usually marked on the tank in the vicinity of the gage glass, make-up feed must be introduced to the condensers to make up the deficiency. Excess feed should normally be dicharged from the system, when necessary, through use of a line provided from the booster-pump discharge beyond the air ejectors to the reserve feed tanks. With main and turbo-generator condensers secured, water may be introduced into the surge tank from the reserve feed tanks by use of the emergency feed pump. This method of adding water to the system should not normally be resorted to, as the water so supplied is saturated with oxygen. Normally, make-up feed should be introduced into the condensers.

9560.251. RAISING VACUUM

When warming up the main propelling units, vacuum should be raised in the main condensers before any condensate is discharged through the feed heaters to the boilers in order to minimize oxygen contamination of boiler feed water. The water necessary for cooling the air ejectors during the warming-up period may be introduced into the condenser hot well from the surge tank through an idle condensate pump. This water is recirculated from the air-ejector discharge line back to the condenser, using the bypass provided around the thermostatic recirculating valve until vacuum is raised and the condenser condensate is cut into the main system.

9560.252. CONDENSATE DEPRESSION

The basic effectiveness of a semienclosed feed system in delivering relatively oxygen-free feed water to the boilers depends upon the ability of the main and turbo-generator to deaerate the condensate and drains collected from the entire system. The difference between the temperature of the condensate in the condenser hot well and the temperature corresponding to the condenser vacuum gives a rough indication of the effectiveness of the condenser as a deaerator. This temperature difference is called "condensate depression" and should be kept as low as practicable under all operating conditions to secure efficiency and effective deaeration. See chapter 9460 for full discussion of condenser operation.

9560.253. CROSS CONNECTING LINES

Figure 9560-7 indicates various cross-connections between engine rooms which are normally provided in connection with the semienclosed feed system. Specimen uses of these several cross-connections are discussed below.

1. **Surge tank cross-connection.**–If necessary to introduce water into a surge tank in a secured engine room, this water may be supplied from the condensate-pump discharge in an adjacent operating engine room through the use of the surge-tank cross-connection. In this way the tank may be filled with reasonable air-free condensate instead of raw reserve feed water as would be the case were the tank filled by the use of the emergency feed pump taking suction from reserve-feed tanks.

2. **Engine-room cross-connection.**-The major purpose of engine-room cross-connecting mains is to provide for flexibility of machinery operation in connection with damage-control considerations. As a secondary function these lines can be effectively used to promote efficient machinery plant operation, enabling engine-room operating personnel to secure certain auxiliary units under low and medium power steaming conditions.

3. **Booster pump discharge cross-connection.**–Booster pump discharges are cross-connected permitting operation at reduced power of two engine rooms with one feed heater and its corresponding group of centrifugal feed pumps, with the other feed-water heater and its corresponding feed pumps secured. Main feed-pump suction lines are cross-connected, between machinery spaces, permitting operation of both engine rooms with any combination of boiler-feed pumps. Cross-connection of feed-pump discharges permits supplying any boiler with feed water from any feed pump. Surge tanks in each engine room are cross-connected, permitting the operation, at reduced power, of both engine rooms with one surge tank secured, making it possible to control make-up feed from a single engine room and decreasing the access of oxygen to the feed water. This surge tank cross-connection should normally be left open when steaming at high power with several boilers in operation in order to make available the maximum surge tank storage capacity for sudden demands incident to unexpected changes in speed of the vessel.

4. **Operation at low and high rates.**-At low ship's speeds with only one feed pump in service, it is usually necessary that the booster pump suction from the surge tanks be closed in one engine room. The booster-pump discharge cross-connection is also closed if the feed heater in each engine room is to be used. With this arrangement the condensate discharge from each unit passes through its own air ejector and the feed heaters in each engine room will receive approximately equal quantities of condensate. The above operating arrangement is usually necessary at low powers because the flow of condensate is such a small part of the rated capacity of the condensate and booster pumps that the pumps will not operate properly in parallel. The condensate discharge from all units is taken by one booster pump if cross-connections are kept open, and the air ejector and feed heaters of the other engine room do not receive feed water. At high ship's speeds all booster pump suctions from the surge tanks should be kept open in both engine rooms as there is sufficient condenser condensate at high power to satisfy the capacity of the pumps and avoid the action described above. If the engine rooms are operated independently at any power with all cross-connections between engine rooms closed and with a feed pump in each engine room in operation, the main booster-pump suctions from surge tanks should be kept open.

9560.254. RECIRCULATION OF CONDENSATE

The use of engine room cross-connecting mains must always be such that condensate from each condenser will pass through its associated air ejector inter and after condensers. The air ejectors use a constant quantity of steam regardless of the ship's speed and a certain minimum quantity of condensate must be discharged through the air-ejector intercondenser under all operating conditions in order to maintain condenser vacuum (see ch. 9460 for discussion of air ejectors). Recirculating lines are provided to return heated condensate from the condensate line beyond the air ejector to the condenser in order to supply an adequate quantity of water to the main and turbo-generator air-ejectors when warming up the plant, steaming at very low powers, maneuvering or standing by. Upon entering the condenser, the heated condensate is flashed to the temperature corresponding approximately to the condenser vacuum, the heat in the flashed steam being absorbed by the condenser cooling-water. The recirculated condensate augments the normal quantity of condensate collected in the condenser from other sources and thus provides sufficient cooling water for proper operation of the air ejectors at low power.

9560.255. THERMOSTATICALLY CONTROLLED RECIRCULATING VALVES

Although recirculation is thermodynamically uneconomical, it is essential in naval installations, where cruising power may normally be only a small fraction of full power, in order to avoid excessive loss of feed water as vapor discharged from the air ejector after condenser vent and to insure proper operation of the air ejectors at fractional power. In order to make recirculation automatic and to avoid excessive recirculation with attendant excessive loss of heat, most air-ejector recirculating lines are fitted with thermostatically controlled valves as indicated in figure 9560-7. These valves are actuated by the temperature of the condensate discharge from the air ejector after condenser. Rise of water temperature above the temperature at which the valve is set results in automatic opening of the valve, recirculating the heated water back to the condenser and through the air ejector again. The thermostatically controlled recirculating valves are adjustable through a range of about 40° F. and should be set in each individual case to open at the highest temperature at which the air ejectors will operate without loss of condenser vacuum or discharge of an appreciable amount of vapor from the air ejector after condenser vent. Thermostatically controlled recirculating valves are provided with bypasses or with manually operated pull-open devices for use when warming up the plant or in the event of derangement of the automatic feature. In the interest of economy, the thermostatically controlled valves should be kept in good condition and properly set and the manual bypasses should be kept closed under all normal operating conditions. The control bulbs of the valves should be located in the condensate line as close to the after condenser discharge as possible or, preferably, within the last pass of the air ejector after condenser water chest when space is available. Instruction booklets furnished by the valve manufacturer should be consulted as to proper position in which the bulbs should be set and instructions for adjustment and maintenance of the automatic equipment.

9560.256. PUMP RECIRCULATION

Manually controlled recirculating lines are provided for centrifugal main feed-pump discharges to provide for discharging sufficient feed through the pump to avoid overheating at very low capacity or when feed checks are closed for short periods under manuevering conditions. These recirculating lines should always be open whenever the feed pump is running in order to avoid possible damage to the pump if operated at no delivery. Recirculating lines from feed booster pump discharges are usually provided to protect the booster pumps and these lines should always be open in cases where this function is not automatically provided for by use of the main feed-pump recirculating line. (see chapter 9470 for detailed information regarding pumps.)

9560.257. OPERATION OF MAIN AND BOOSTER FEED PUMPS

The feed booster pumps may be regarded as the first stage of the boiler feed pumps. Under no circustance should a centrifugal, main boiler feed pump installed in a system having feed booster pumps be operated unless one or more booster pumps are in operation because the feed pumps would receive no water and would be damaged. Thus the booster pumps should always be started before the centrifugal boiler feed pumps and conversely the centrifugal boiler feed pumps should be secured before securing the booster pumps. Since the booster pumps are but a first stage of the centrifugal feed pumps, the capacity of the feed system at any time is limited by the number and size of the booster pumps in operation. It is important when taking a feed pump out of service that the feed-pump discharge valve be closed before the pump is stopped in order to minimize pump damage which would occur if the feed check valve in the pump discharge should stick open, causing the pump to run backwards.

9560.258. EMERGENCY FEED PUMPS

Reciprocating emergency feed pumps are provided for all vessels equipped with the semienclosed feed system. As their name implies, they are primarily installed as a source of supply of boiler feed water in emergencies and should always be kept in stand-by condition when the vessel is underway. In the event of unexpected loss of the normal boiler feed water supply due to a feed-pump derangement or other cause, emergency feed pumps are immediately started taking suction direct from a reserve feed tank and discharging through the economizers to the boilers to avoid a boiler casualty.

9560.259. OTHER USE OF EMERGENCY FEED PUMPS

The emergency feed pump is normally arranged to perform several important functions in addition to its primary function of supplying cooled feed water from the reserve feed tanks to the boilers in emergencies. Many vessels are not provided with port use feed pumps and the emergency feed pump is normally used to handle boiler feed water in port, taking suction from the main condensate line. Distribution of reserve feed water among reserve feed tanks is another normal function of the emergency feed pump. It is also employed to pump out the boilers by use of portable hose lines. As noted in article 9560.250, the emergency feed pump is sometimes used for filling the surge tank.

9560.260. SECOND STAGE FEED HEATER

1. Some naval vessels are provided with a second stage feed water heater located in the main feed discharge line between the boiler feed pump and the boiler. The second stage feed heater is provided to improve the thermodynamic efficiency of the feed cycle usually using steam bled from the main propulsion turbines at a pressure materially higher than that normally carried in the auxiliary exhaust system. Second stage feed heaters are generally similar to the straight tube or U-tube type feed heaters described in section II, part 2, except that the feed heater shell is designed to withstand the higher steam side operating pressure, and shell relief valves are set at a correspondingly higher value. Second stage feed heater drains are discharged through an automatic drainer to the first stage feed heater shell.

2. In most naval installations where economizers are provided, the extra weight, space, and complications involved in the use of second stage feed heaters are not usually justified. The saving in weight of cruising radius fuel from the improved plant efficiency is usually not sufficient to compensate for the added weight of feed heater and piping.

9560.261. SUMMARY OF IMPORTANT OPERATING REQUIREMENTS

1. Inspect and clean filter frequently (articles 9560.215, 9560.216, 9560.248).

2. Raise vacuum in condensers before discharging condensate to boilers (article 9560.251).

3. Operate condensers to secure minimum practicable condensate depression (article 9560.252).

4. Open feed-pump recirculating lines whenever pumps are operated (article 9560.256).

5. Never operate feed pumps in systems provided with feed booster pumps unless the feed booster pumps are running (article 9560.257).

6. Test feed heaters and relief valves to one and one-half times the maximum working pressure after overhaul or repairs (articles 9560.230, 9560.231, 9560.244, 9560.260).

7. Take make-up feed through condenser (article 9560.250).

Part 4-Vacuum Closed Feed System

9560.271. GENERAL

The vacuum closed feed system is installed in many naval vessels having main steam pressures between 400 and 1200 pounds per square inch. This type of feed system, unlike the open feed system and the semienclosed feed system, eliminates entirely the free access of atmospheric air to the feed water at any point. Referring to figure 9560-8, condensate from the condensers is pumped by the condensate pumps to the surge tank, which is maintained under substantially the same vacuum as that existing in the condensers by means of vent lines connecting the top of the surge tank to the steam side of the condensers. Booster pumps take suction from the surge tank and discharge via the air-ejector condensers and feed-water heaters to the boiler-feed pumps, providing a substantial positive head at the main feed-pump suction. The feed pumps discharge through economizers to the boilers.

9560.272. DISTINCTION BETWEEN VACUUM CLOSED AND SEMIENCLOSED SYSTEM

The surge tank constitutes the basic difference between the semienclosed and vacuum closed feed systems. In the former, the surge tank floats on the main feed-pump suction; in the latter, all condensate is discharged through the surge tank which is maintained essentially at condenser vacuum since it is vented to the main condenser. Feed booster pumps are essential to the vacuum closed feed system, but their provision in the semienclosed feed system may be optional.

9560.273. SURGE TANK

The vacuum surge tank is elevated, as in the case of the atmospheric surge tank of the semienclosed feed system, to provide safe operating suction head at the feed booster-pump suction. Since the booster pumps of the vacuum system must handle water at a temperature very close to its boiling point for the existing vacuum, booster pumps are located directly below the surge tank and direct suction lines of ample size are provided. Provision is made for constant boiling of the water contained in the surge tank, making use of auxiliary exhaust or the heat available in high-pressure drains and the water should be boiled constantly during operation both underway and in port. The tanks are provided with two thermometers, one near the bottom and one slightly below the operating water level. If the lower thermometer indicates a lower temperature than the upper thermometer during normal operation, it is indicated that the water in the tank is not boiling, and additional heat should be supplied from high-pressure drain or auxiliary exhaust. By this means the oxygen content of the condensate is maintained at a relatively low value as air is insoluble in water at its boiling point. (See article 9560.31.)

9560.274. ELIMINATION OF AIR LEAKAGE

It should be noted that boiling the water in the surge tanks only renders oxygen insoluble. Thus the elimination of air leakage in the vacuum lines is highly important. Constant vigilance should be maintained to detect and correct air leakage into vacuum lines. It will be noted that the vacuum closed feed system has many more feed water lines under vacuum than the semienclosed feed system and air leaks must be eliminated throughout the vacuum system, including condensate pump suction and discharge lines, booster-pump suction lines, condensate pump suction and surge-tank cross-connecting lines, surge-tank vent lines, vent cross-connection, etc. As in the case of the semienclosed feed system, reduction of condensate depression to the minimum obtainable value is essential to the operation of the system to produce relatively oxygen-free boiler feed water. (See article 9560.252.)

9560.275. OPERATION OF SURGE TANK UNDER ATMOSPHERIC PRESSURE

In general the surge tanks should be maintained at condenser vacuum under all operating conditions. However, in the event of damage to the surge tank or its connecting vacuum lines, the surge tank may be operated under atmospheric pressure, when necessary in emergencies, to avoid loss of condenser vacuum. Under this method of operation the surge tank vent lines are secured at the condensers and the surge tank pressure becomes atmospheric. The condensate pumps, discharging against atmospheric pressure, require greater submergence; i.e., condensate builds up in the condenser hot wells. When making high power with atmospheric pressure in the surge tank, condensate pumps may be inadequate to prevent condensate from rising in the condenser to the point where part of the condensing service is flooded with consequent reduction in condenser vacuum.

9560.276. BYPASSING SURGE TANKS

An alternate method of emergency operation in the event of damage to the surge tanks is to bypass the tanks completely through use of a bypass provided to connect the condensate-pump discharge directly with the booster-pump suction, and exercising careful manual control of make-up and excess feed.

9560.277. ATMOSPHERIC OPERATION FOR EMERGENCY ONLY

The surge tanks should never be operated under atmospheric pressure except in emergencies and valves in vacuum vent lines connecting with the condensers should be fully open under all normal operation.

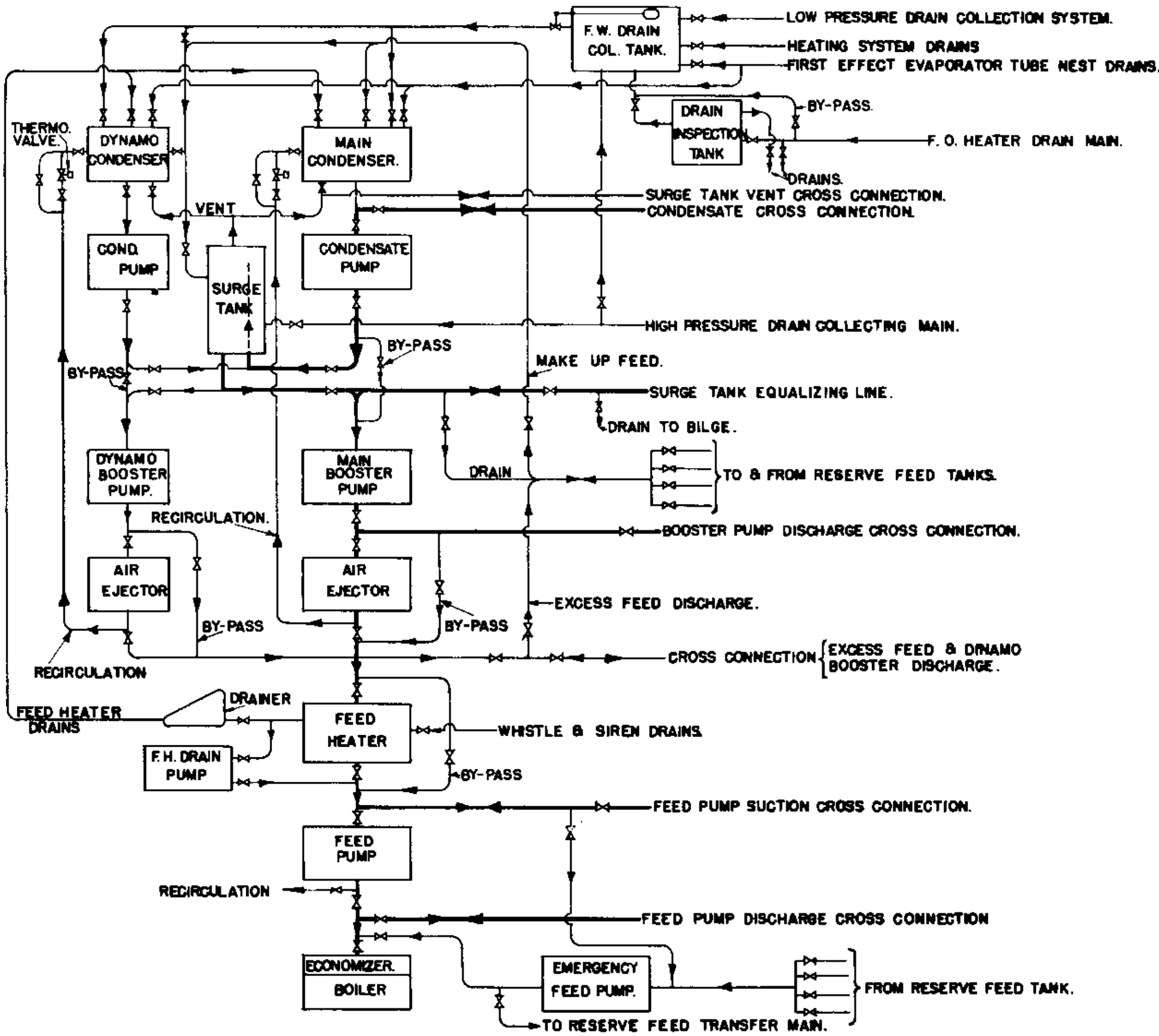


Figure 9560-8

9560.278. RAISING VACUUM

1. Normally when making preparations to get underway, the turbo-generator condensing plant will be in operation with vacuum on one of the surge tanks and the surge tank in the other engine room secured. It is essential when warming up the main plant that the introduction of air to the feed circuit be avoided as far as possible. Provision is, therefore, made in the arrangement of the feed and condensate piping so that neither the main nor the turbo-generator condensers should be placed in the boiler feed water circuit until high vacuum has been established in the condensers and surge tanks. A bypass connection is, therefore, provided to connect the discharge of the condensate pumps with the suction of the corresponding booster pump. When warming up or securing, this bypass should be in use so that the condensate pump forms the first stake of the booster pump, bypassing the surge tank. The condensate outlet valve between the air-ejector condensers and the feed water heater is closed and the recirculating line connecting this section of the condensate line with the condensers is opened. The condensate handled by the condensate and booster pumps is permitted to flow through the air-ejector condensers and back to the main or turbo-generator condensers through the recirculating line, thus bypassing the thermostatically controlled recirculating valve provided in the recirculating line.

2. By this arrangement vacuum may be raised in any main or turbo-generator condenser independently of the remainder of the feed system; the air ejectors may be started, cooled with condensate which is recirculated, and in turn cooled in the condensers. This method of warming up should be continued until a condenser vacuum of about 27 inches Hg. is obtained. When this vacuum has been obtained, the bypass between the outlet of the condensate pump

and suction of the booster pump may be closed, the discharge from the condensate pump to the surge tank opened (suction of the booster pump being transferred to the surge tank), the booster-pump discharge valve between the air ejector and the feed water heater opened, and the bypass around the thermostatically controlled recirculating valve in the recirculating line closed. The system will thus be placed in normal operating condition. The bypass around the thermostatically controlled valve should remain closed during normal operation (see article 9560.255).

3. During the above warming-up procedure it is necessary that a certain amount of make-up feed water be introduced into the main condenser hot wells before starting the pumps and the air ejector, to supply the cooling medium for the air ejector inter and after condensers. This water may be introduced into the condensers before the pumps are started by slightly opening the valve in the booster-pump discharge line to the feed heater, allowing condensate under pressure from the dynamo booster-pump to back up into the condenser via the booster pump and condensate pump.

9560.279. MAKE-UP FEED

Under steady operating conditions make-up feed is introduced to the condensers as necessary through the make-up feed line connecting with the reserve feed tanks. The make-up feed line also connects to the surge tank but make-up feed should never be introduced into the surge tank except in emergencies as better deaeration results through introduction into the condensers.

9560.280. EXCESS FEED

Under normal operating conditions, excess feed is discharged to the reserve feed tanks through lines connecting the main condensate line beyond the air ejectors to the reserve feed manifold. When operating with the surge tanks at atmospheric pressure (see article 9560.277), water may be drained from the surge tanks either to the bilge or back to the reserve feed through drain lines provided.

9560.281. FLUCTUATION IN SURGE TANK LEVEL

During maneuvering of the vessel it is entirely normal for the water level in the surge tank to fluctuate to some extent, and there is usually no need, during maneuvering, for the admission of make-up feed to the system or the discharge of excess feed, unless the surge-tank level rises above or falls below the normal maneuvering levels, which in most cases are marked on the tank adjacent to the gage glasses. For example, when going from full speed ahead to full speed astern, the water level in the surge tank will go down as the ahead throttles are closed and will rise shortly thereafter when the astern throttle has been opened wide. If no make-up feed or excess feed is discharged during the cycle, the water in the surge tank will usually assume the normal level when steady operation astern has been established.

9560.282. DRAIN DISPOSAL

Most shipboard installations of the vacuum-closed feed system are arranged so that the feed heaters can be drained either to the condenser or, via a feed-heater drain-pump, into the main feed-pump suction. Feed heaters should be drained to the condenser, except in an emergency. If it is found necessary to augment the booster-pump discharge-pressure under high-power steaming conditions, the feed-heater drain-pump may be used. When this pump is started under way, care must be taken to open the discharge valve slowly in order to avoid surging throughout the entire feed system of the water being handled by the sudden introduction of an increased quantity of condensate to the feed-pump suction. Use of the feed-heater drain-pump will introduce some undeaerated feed-heater drains directly through the feed pump to the boilers. Discharge of feed-heater drains to the condensers provides for better deaeration and the thermodynamic loss involved is more than justified.

9560.283. FUEL OIL HEATER DRAINS

Fuel-oil heater drains are usually discharged through a drain inspection tank to the fresh-water drain collecting tank as indicated in figure 9560-8. The drain inspection tank provides a water seal and any oil contamination of the drains can be observed through illuminated glasses provided in the sides of the tank. Provision is made for discharging these drains to the bilge in the event of contamination. Oil contamination of condensate in vessels provided with the vacuum closed feed system is not likely to occur in any parts of the system except the fuel-oil or lubricating-oil heating equipment which drains to the drain inspection tank. Therefore, in most installations no filters are provided in the feed system and care must be exercised in detecting any oil leakage in fuel-oil heater drains before remainder of the system is affected. In this connection frequent inspections of the drain tank, which is usually located conveniently adjacent to the engine-room operating station, should be made.

9560.284. FRESH WATER DRAIN COLLECTING TANK

The fresh-water drain collecting tank discharges to the condensers and receives drains from the drain inspection tank, the ship's heating system, low-pressure drain collecting system, air ejector condensers, etc. A connection is provided for discharging tank drains to the surge tank, but this method of drain disposal should never be used except in emergencies, as better deaeration results when these drains are discharged direct to the condensers. First effect evaporator tube nest drains may be discharged to the fresh-water drain collecting tank unless drainage through the alternate line to the condensers is necessary to drain the evaporators properly. High-pressure drains should normally be discharged to the surge tank to provide for boiling of the condensate, but provision is usually made for discharging these drains to the fresh-water drain collecting tank in emergencies.

9560.285. CROSS-CONNECTING MAINS

It will be noted from figure 9560-8 that several engine-room cross-connecting mains are provided in connection with the vacuum closed feed system. Through use of the surge-tank equalizing line and the condensate cross connection it is feasible to operate both propelling units at cruising power with only one condensate pump in operation. As condensate and booster pumps are usually combined in one assembly on a single shaft, it is necessary, under this condition, that booster-pump recirculating lines be opened so that they will not heat up and be damaged due to operation at no delivery. The feed-pump suction and discharge cross connections permit any main feed pump to take suction from either engine room and discharge to any of the vessel's boilers.

9560.286. RECIRCULATION

Operation of many of the units of the vacuum closed feed system is generally similar to similar units of the semienclosed feed system discussed in section II, part 3. Reference should be made in this connection to articles in section II, part 3 describing operation of centrifugal-pump recirculating lines, thermostatic recirculating lines, emergency feed pump, etc.

9560.287. SUMMARY OF IMPORTANT OPERATING REQUIREMENTS

1. Boil water in surge tank continuously both in port and under way (article 9560.273).
2. Maintain constant vigilance to avoid air leaks into feed and condensate lines (article 9560.274).
3. Operate condensers to secure minimum practicable condensate depression (article 9560.274).
4. Raise vacuum in condensers before discharging condensate to boilers (article 9560.278).
5. Bypass feed heater drain pump during normal operation (article 9560.282).
6. Never operate centrifugal feed pumps unless feed booster pumps are operating (articles 9560.257, 9560.286).
7. Test feed heaters and relief valves to one and one-half times the maximum working pressure after overhaul or repairs (articles 9560.230, 9560.231, 9560.286).
8. Take make-up feed through condenser (article 9560.279).

Part 5–Pressure-Closed Feed System

9560.291. GENERAL

The semienclosed feed system and the vacuum closed feed system have been superseded by the pressure closed feed system. The basic difference between the pressure closed feed system and the earlier designs is that it provides a deaerating feed tank which combines the functions performed by the surge tank and the feed heater of the earlier systems. The deaerating feed tank performs an additional function in effecting final deaeration of all condensate and drains prior to discharge of feed water to the boilers. The earlier feed systems relied on main and turbo-generator for deaeration of feed water and under optimum operating conditions the amount of dissolved oxygen in the feed water corresponded closely to that of the condenser condensate. In the pressure type deaerating feed system, final reliance is placed on the deaerating feed tank for removal of dissolved oxygen from condensate, drains, and all other feed water components. With proper operation, deaerating feed tanks will always reduce the dissolved oxygen content of boiler feed water below 0.02 ppm, and frequently to less than 10 percent of that limit. Instructions for checking the performance of deaerating feed tanks are given in section I, part 6.

9560.292. ARRANGEMENT OF SYSTEM

Referring to figure 9560-9, condensate from the main and turbo-generator condensers is discharged by the condensate pumps through the air-ejector condensers to the deaerating feed tank via the gland exhaust condenser and the deaerating feed tank vent condenser. Feed booster pumps which in turn discharge through the economizers to the boilers. It will be noted that the entire main condensate system is under pressure throughout with the exception of the short direct condensate pump suction lines.

9560.293. FUNCTION OF DEAERATING FEED TANK

The major functions of the deaerating feed tank include: provision of a storage reservoir in the feed system to insure stable operation under conditions of rapidly fluctuating load; heating the feed water to a temperature closely approaching that corresponding to the pressure of auxiliary exhaust steam; deaeration of the heated feed water; and maintenance of the reserve supply of feed water in the lower part of the tank in a thoroughly heated and deaerated condition. Deaerating feed tanks are designed to remove dissolved gases by use of the principle that the solubility of gases in feed water approaches zero when the water temperature approaches the boiling point, as outlined in article 9560.22. Although heating the water to the boiling point renders the dissolved gases insoluble, it is necessary to provide positive means for removal of the gas molecules still entrained in the heated water in order to secure complete deaeration. The vacuum surge tank of the vacuum closed feed system, discussed in part 4, provides for boiling the condensate but complete deaeration of the water in the surge tank is not attained because the means provided for removal of the gas molecules entrained in the heated condensate are inadequate.

9560.294. DEAERATING FEED TANK

In the deaerating feed tank the boiler feed water is heated and deaerated by direct contact with auxiliary exhaust steam. Figures 9560-10 and 9560-11 indicate diagrammatically the basic arrangement of the types of deaerating feed tanks commonly used in naval installation. The way in which the deaerating feed tank performs its function is described in articles 9560.295 to 9560.297, below. The flash type deaerating feed tank, very few of which remain in naval vessels, is not covered by this discussion.

9560.295. WATER FLOW

The mixture of condensate, drains, and make-up feed water, constituting the inlet water to the deaerating feed tank, enters through the tubes of the vent condenser. By the pressure of the condensate pump discharge it is forced through the numerous spray valves of the spray head and discharged in a fine spray throughout the steam-filled top or preheater section of the deaerating feed tank. The tiny droplets of water are heated and scrubbed by the relatively air-free steam so that virtually all of the dissolved air is released. The drops of heated water fall through the steam atmosphere and are collected by a conical baffle which conducts them to a central port. Here the partially deaerated and heated water is picked up by the incoming exhaust steam and thrown radially outward and upward against the lower side of the conical baffle in a finely atomized spray.

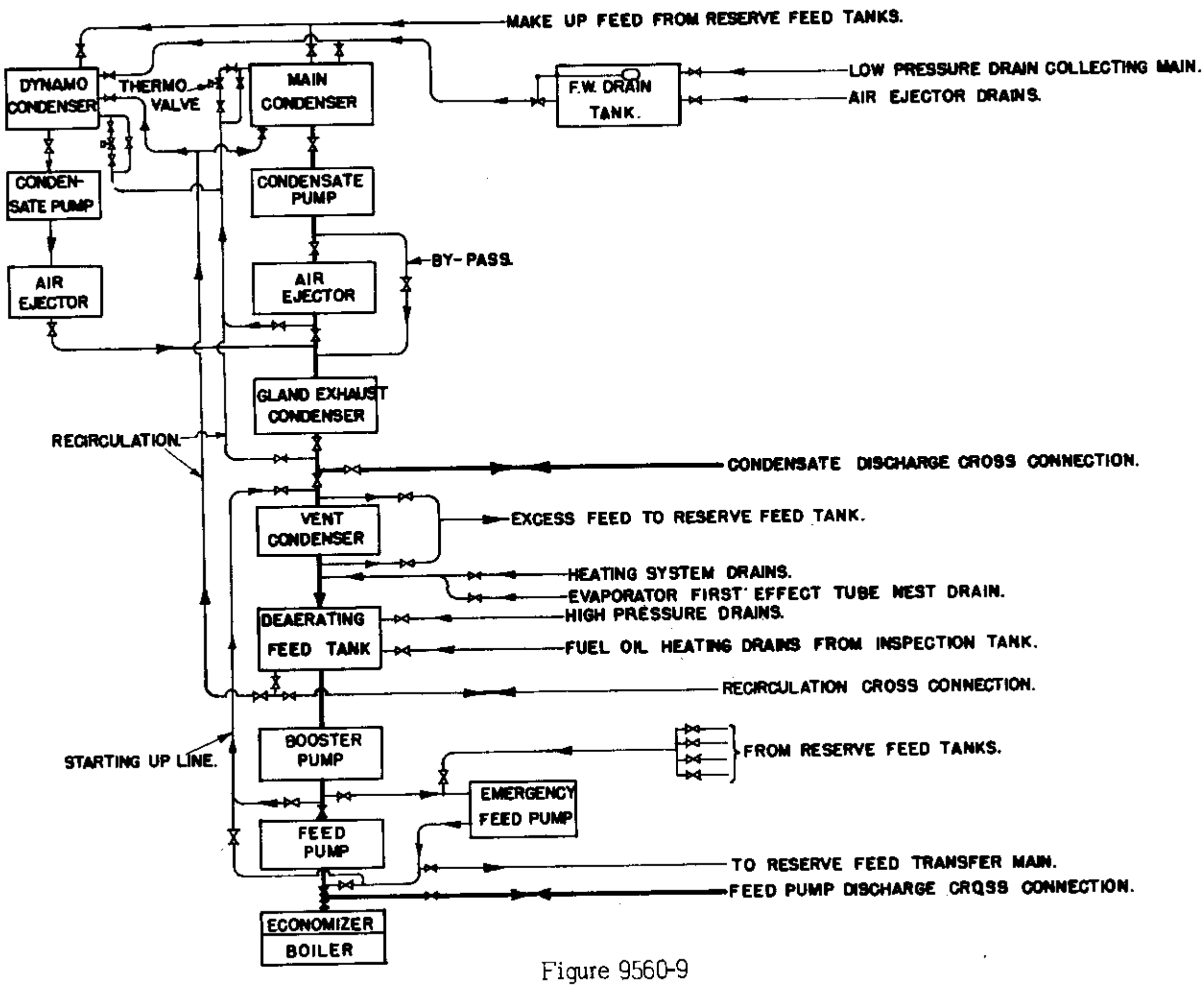


Figure 9560-9

The mixture of steam and water attained by this spray nozzle is so intimate and complete that the water and steam reach an equilibrium temperature and the dissolved gases in the water are removed. The water then falls into the storage space at the bottom of the tank where it remains under a blanket of air-free steam until needed for the boilers. Vertical radial or spiral baffles usually are attached to the upper surface of the collecting cone and to that of the spray nozzle, if it is large, so that the deaerating function can proceed regardless of roll or pitch of the ship.

It will be obvious that should a spray nozzle or nozzles stick open, or if a spray nozzle spring is broken, the resultant flow from the nozzle will not be in the form of a fine spray and, therefore, deaeration will be impaired. Such a condition cannot be discovered except by analysis of the feed water leaving the DFT or by inspection of the spray nozzles. On those vessels which are not provided with dissolved oxygen test kits, inspection of the spray nozzles should be scheduled at frequent intervals. A manhole is provided in most of the DFT's for access to the spray nozzles, while others are so designed that the spray nozzle chamber is removed with the vent condenser.

9560.296. STEAM FLOW

Auxiliary exhaust steam flows directly into the spray head. Either in the spray head or in the line leading thereto a check valve is provided so that steam can flow from the auxiliary exhaust line whenever the pressure within the deaerating feed tank is less than that in the exhaust line but which will prevent the return flow of water into the auxiliary exhaust line in case the deaerating feed tank should be flooded. In the spray head the incoming steam atomizes the preheated water, as described above, heating it to equilibrium temperature and scrubbing from it the last traces of dissolved air. A portion of the incoming steam is condensed in this process, the condensate collecting with the heated and deaerated feed water in the bottom of the surge tank. The uncondensed steam flows around the conical baffle into the preheater section of the deaerating feed tank where it mixes with the incoming water being discharged by the spray head. Here another stage of heating and deaeration occurs, a large proportion of the residual steam being condensed in the process. The remaining steam flows into the shell of the vent condenser where it is further condensed by heating the incoming water passing through the tubes. The condensate from the shell of the vent condenser drains onto the conical baffle separating the preheater and

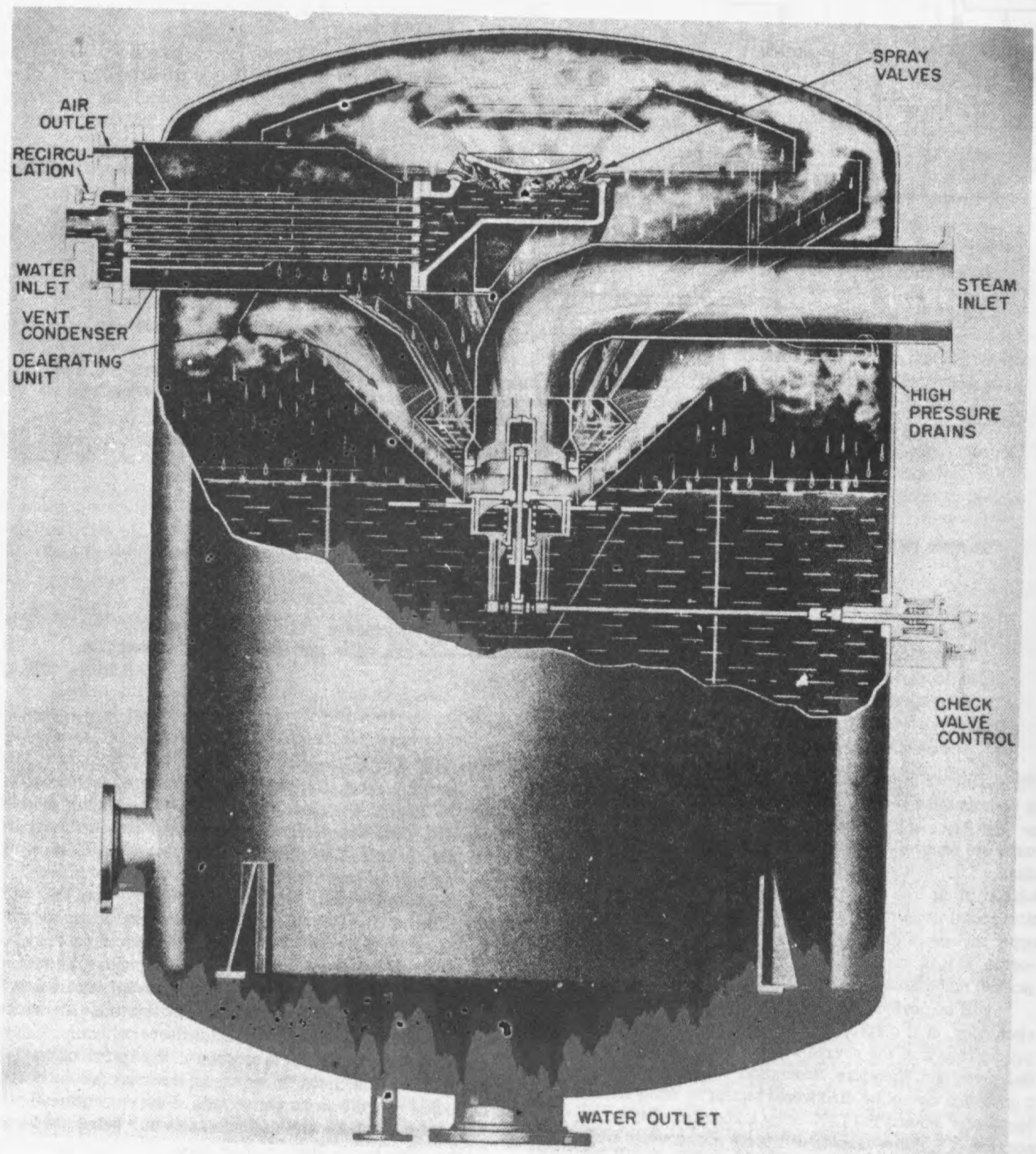
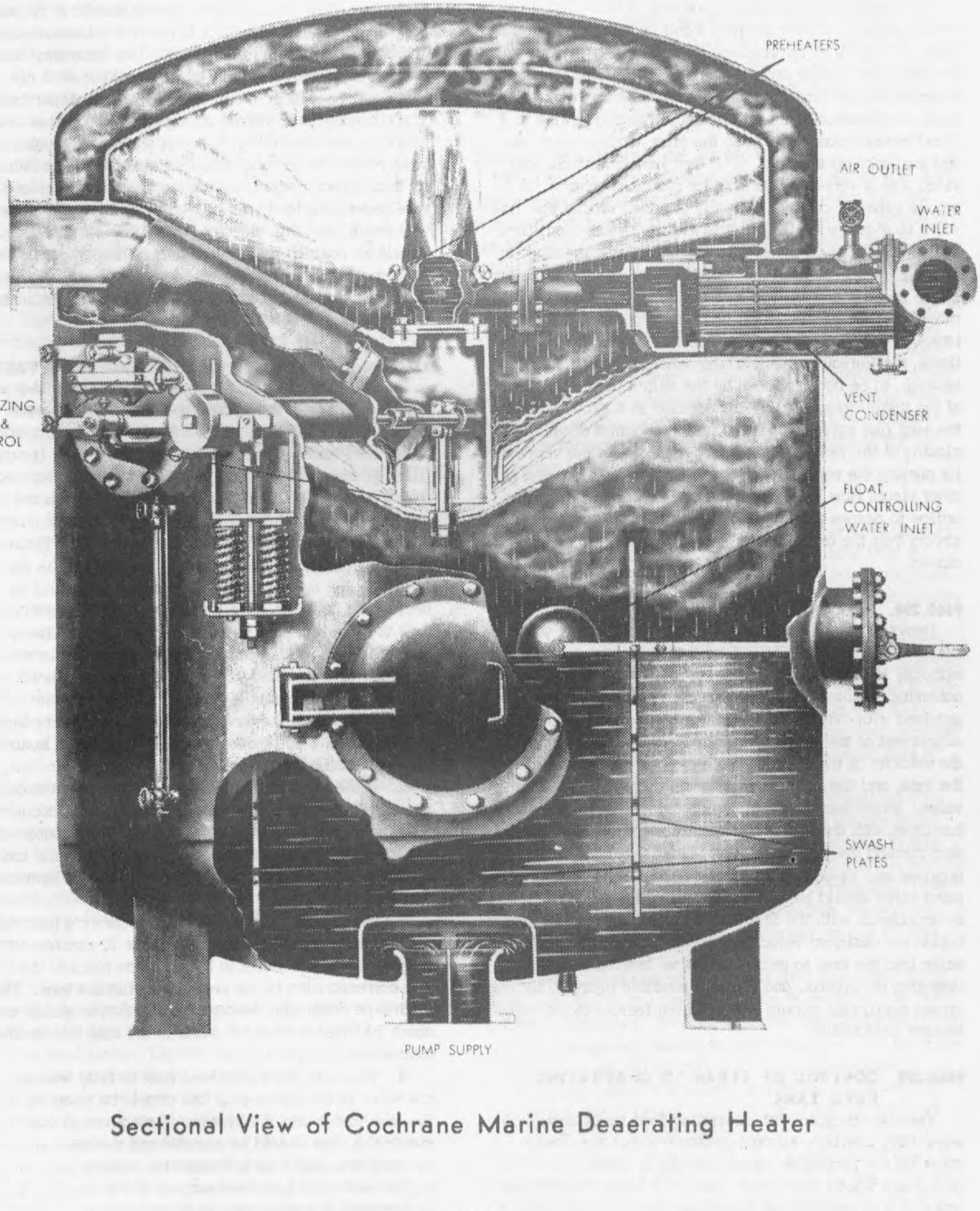


Figure 9560-10. Sectional View of Cochrane Marine Deaerating Heater.



Sectional View of Cochrane Marine Deaerating Heater

Figure 9560-11.

storage portions of the deaerating feed tank so that this condensate is recycled through the spray nozzle. The steam not condensed in the vent condenser flows out through the vent line of the vent condenser, carrying with it all of the dissolved air which has been removed from the incoming feed water.

9560.297. VENTING

To complete the deaerating process, it is necessary that air separated from the feed water be removed from the tank. If this air is not removed, it will be redissolved in the feed water in the storage section of the tank. Removal is accomplished through a vent from the vent condenser. In most installations, the vent discharges through a line to a gland exhaust condenser or to the after condensers of main and auxiliary air ejectors. The vent line is normally provided with a valve of line size for maximum venting. A needle valve or orifice is usually provided around this line valve to regulate venting in less than maximum quantities. In investigations of boiler-tube corrosion, it was found, in several instances, that the corrosion was directly attributable to the fact that vent line and needle valves were closed and the separated air had not been removed from the tanks. To insure positive and continuous venting at all times, the Bureau has authorized, where applicable, an alteration, to be accomplished by the ship's force, consisting of the installation of a 3/8-inch orifice in a bypass around the vent line valve. This will provide against complete closing of the vent line and will permit use of the vent valve for purging the tank, if necessary. A simple manometer or other visual flow indicator should be installed across the orifice to assure that there is flow and that a valve downstream from the orifice has not been inadvertently left closed.

9560.298. INTERNAL CHECK VALVE

Remote operating gear is provided for the check valve mentioned in article 9560.296 so that it may be operated manually if necessary in the event of derangement of the automatic feature. Some types of deaerating feed tanks are provided with external automatic operating mechanism for adjustment of the internal check valve, in order to control the velocity of the steam issuing through this valve into the tank, and the valve in this case is termed an atomizing valve. Where such mechanism is provided, instruction books furnished with the equipment specify the proper pressure drop through the atomizing valve, usually between three-quarters and 1½-pounds per square inch. The check or atomizing valve should be kept in proper adjustment at all times, in accordance with the instructions provided, in order to obtain the designed velocity of steam issuing through the valve into the tank to secure effective deaeration under operating conditions, and to avoid possible injury to turbine-driven auxiliaries should the nonreturn feature of the valve become inoperative.

9560.299. CONTROL OF STEAM TO DEAERATING FEED TANK

Vessels equipped with deaerating feed tanks should always carry auxiliary exhaust pressure within the design range for the particular vessel, usually between 10 and 15 pounds per square inch gage. Main and turbo-generator turbines of such vessels are sometimes equipped with turbine bleeder connections to be used to augment the auxiliary exhaust supply as necessary to provide low-pressure steam for heating the feed water, and for operation of the distilling plant. In addition, augmenting valves are (usually 150 psi system) ordinarily provided to bleed live steam into the auxiliary exhaust main should the pressure fall below the minimum auxiliary exhaust pressure necessary for proper operation of the deaerating feed tanks, usually 8 pounds per square inch gage. These augmenting valves should be regarded as for emergency use only as it is relatively uneconomical to use live steam for heating feed water. The deaerating feed tank steam supply valves should always be kept wide open when this equipment is in use in order to secure proper deaeration. Throttling of these valves during normal operation in an attempt to control auxiliary exhaust pressure through adjustment of feed water temperature is specifically prohibited for both direct-contact type deaerating feed tanks and flash-type deaerating feed tank as improper feed water deaeration will result from this practice. Auxiliary exhaust pressure should be controlled, instead, through the proper use of main and auxiliary turbine bleeder valves and by operation of turbine driven or motor driven auxiliaries when alternate units are provided for a given service.

9560.300. WARMING UP DEAERATING FEED TANK

1. It is important that a secured deaerating feed tank be kept isolated from the system and its contained water deaerated before the tank is cut into the system to supply boiler feed water. If the secured tank is empty, it may be filled by means of the emergency feed pump taking suction from a reserve feed tank and discharging through the starting up line indicated in figure 9560-9 to the main condensate line just ahead of the vent condenser. During this operation auxiliary exhaust should be supplied to the deaerating feed tank in order that the incoming water will be heated and deaerated. In warming up a cold deaerating feed tank the steam supply valve should be opened **slowly**, in order to avoid sudden temperature changes within the tank. When the tank is filled to the normal operating level, a feed booster pump should be employed to circulate the heated water from the tank back through the vent condenser via the starting-up line for about 10 minutes, to insure complete deaeration of the water.

2. If the secured deaerating feed tank is not empty, it may be warmed up by use of a booster pump in connection with the starting-up line for recirculating the contained water. Auxiliary exhaust steam is supplied to the tank during recirculation and the water is gradually heated and deaerated.

3. In the case of direct-contact deaerating feed tanks, recirculation should continue for about 10 minutes after the temperature of the water in the tank has reached the temperature corresponding to the pressure within the tank. The flash-type deaerating feed tank recirculation should continue about 10 minutes after the water in the tank has reached a temperature of 212° F.

4. When the deaerating feed tank is fully warmed up, the valve in the starting-up line should be throttled before the tank is cut into the system. During normal operation the starting-up line should be secured and the feed pump recirculating line relied on to protect the booster pump as well as the feed pump from overheating. If the starting-up line is permitted to remain open during the normal operation, im-

proper deaeration will result because the large quantity of heated water recirculated through the vent condenser reduces its effectiveness in removing the air vapor mixture from the deaerating feed tank.

9560.301. RAISING VACUUM

When warming up a second main propelling unit, it is desirable that full vacuum be obtained in the main condenser before any condensate is admitted to the boiler feed system. This may be accomplished by recirculating condensate from the air ejector discharge back to the main condenser hot well, bypassing the thermostatic recirculating valve during the warming-up period. The water necessary for recirculation is admitted to the main condenser initially through a line connecting the storage section of the deaerating feed tank with the condenser. When full condenser vacuum is obtained, the manually controlled bypass around the thermostatic recirculating valve is secured and the valve in the main condensate line beyond the air ejector is open to cut the condenser into the system.

9560.302. CONDENSATE RECIRCULATION

Under normal operating conditions recirculation to the main condenser at light loads is automatically controlled by the thermostatic recirculating valve. Water for normal recirculation is taken from the main condensate line either beyond or ahead of the vent condenser, and the branch of the recirculating line from the air ejector discharge should remain secured except when warming up the plant. Recirculation of water taken from the condensate line beyond the vent condenser assures proper functioning of the deaerating feed tank at light loads, but involves the use of recirculation cross-connection when engine rooms are running cross-connected.

9560.303. RECIRCULATION FROM DEAERATING FEED TANK

Provision is made for recirculation from the storage section of the deaerating feed tank to main and dynamo condensers. This line is necessary to supply water to the condenser hot wells prior to warming up the system, and under conditions of operation when insufficient water is supplied to the gland exhaust condenser and the deaerating feed tank vent condenser through normal functioning of the thermostatically controlled recirculating valve. Recirculation from the storage section of the deaerating feed tank to the condenser hot wells should be avoided during normal operations, as recirculation of the heated water through this line is less economical than recirculation of the cooler water from the main condensate line ahead of the deaerating feed tank.

9560.304. MAKE-UP FEED

Make-up feed is admitted to main and dynamo condensers as necessary through the make-up feed line connecting with the reserve feed tanks. Excess feed is normally discharged to reserve feed tanks from the main condensate line beyond the gland exhaust condenser or, in the case of some installations, beyond the deaerating feed tank vent condenser. Sufficient volumetric capacity is provided in the deaerating feed-tank storage section so that the discharge of excess feed or admission of make-up feed should be unnecessary when the vessel is maneuvering. As in the case of the surge tank provided in other feed systems, deaerating feed tank water level may fluctuate rapidly during maneuvering conditions, but will not normally rise above or fall below the high and low operating levels marked on the deaerating feed tank in the vicinity of the gage glass. Deaerating feed tank gage glasses should be of the shatterproof reflex type if visibility over a limited arc is satisfactory. For installations where visibility over a large arc is necessary, as in the case of most vessels having two engines installed in one engine room, the ordinary tubular gage glass should be retained; a small reflex type gage glass being provided to cover the normal operating range. With this installation, the tubular gage glass cocks may be used as dry cocks in the event of casualty to the glass.

9560.305. TRANSFER OF FEED WATER

When engine rooms are running cross-connected with more than one deaerating feed tank in operation, water may be transferred from one tank to another, if necessary, by use of the manually controlled bypass around the thermostatic recirculating valves. Opening the recirculating line in one engine room reduces the pressure in the main condensate line, thereby permitting some of the water delivered by the condensate pumps in another engine room to be discharged through the condensate cross-connecting line, raising the deaerating feed tank level. This method of operation avoids the necessity of discharging excess feed to a reserve feed tank in one engine room and then admitting it in another engine room through the make-up feed connections to control deaerating feed tank levels.

9560.306. OPERATION UNDER WAY

1. When operating cross-connected, one or more deaerating feed tanks are normally secured, condensate from the propelling unit associated with the secured deaerating feed tank being transferred to another engine room via the condensate discharge cross connection. When running cross-connected in this manner, the boiler feed pumps associated with the secured deaerating feed tank should not be operated unless the feed pump recirculating lines are arranged to discharge into a deaerating feed tank which is in operation. This is to prevent hot feed pump recirculation from overheating the idle deaerating feed tank, with a resultant loss of heat through the deaerating feed tank vent.

2. Some installations are provided with combined condensate and feed booster pumps so that the booster pump cannot be secured when running cross-connected. In this case the valve in the starting-up line from the idling booster pump should be cracked open to prevent overheating of the pump. Vapor generated by recirculation from the booster pump escapes through the vent condenser vent under this condition.

3. Securing of one or more deaerating feed tanks when under way at low and medium speeds is desirable, as more effective deaeration is obtained in the operating tanks, control of make-up and excess feed is simplified, and some improvement in overall operating economy is obtained.

4. Under normal split plant operations, all deaerating feed tanks should be put into service. Each engine room may then be operated independently and cross-connecting lines between engine rooms secured. If the water level rises in one deaerating feed tank while it falls in another, feed may be transferred between tanks through the condensate cross-

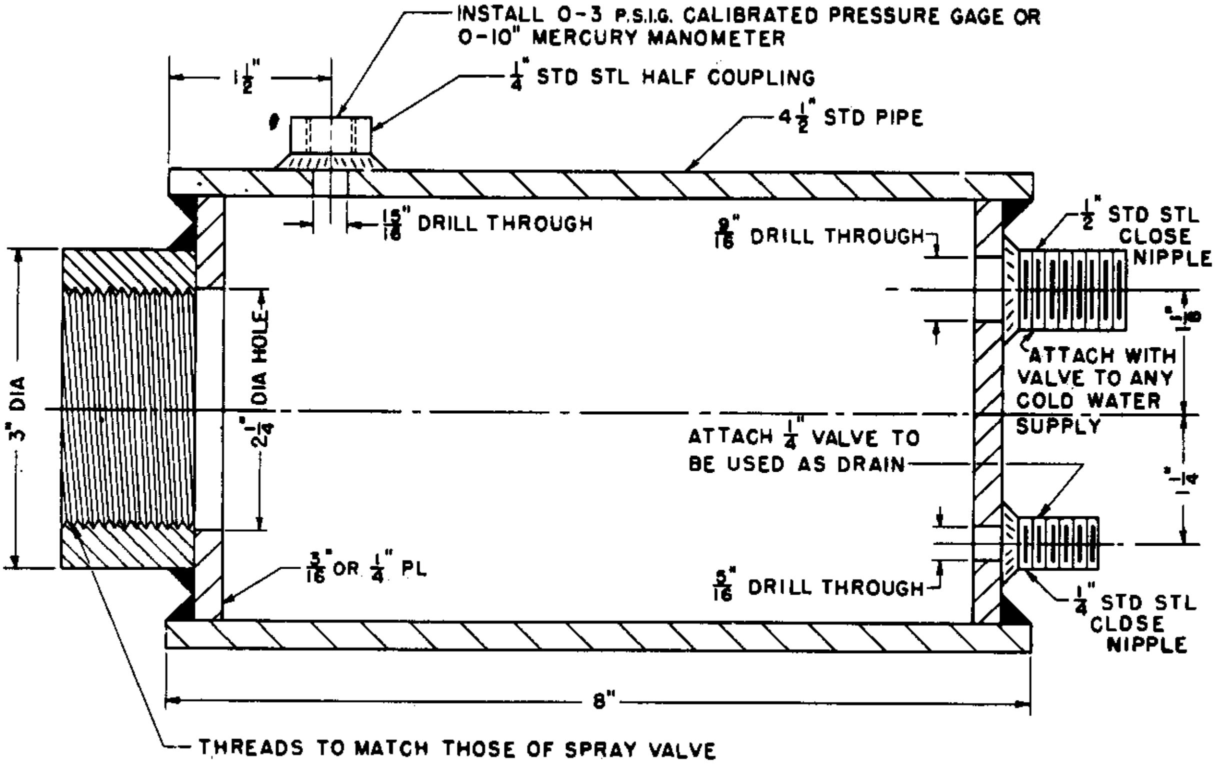


Figure 9560-12

connecting main, as outlined above, avoiding excessive use of excess feed discharge and make-up feed admission lines.

9560.307. OPERATION IN PORT

1. Normal operation of the feed system in port with the main propelling units secured involves the securing of all but one of the deaerating feed tanks and using the emergency or port use feed pump for supplying water to the boilers in operation. Since the steam load is usually very small, the reciprocating type emergency feed pump may be operated intermittently so that the valve in the starting-up line should be open slightly to provide continuous recirculation through the booster pump.

2. If an unusually large quantity of feed water is required under port operating conditions for any purpose, such as for filling boilers, condensate and booster pumps of a main propelling unit may be started. A sufficient quantity of make-up feed should be admitted to the main condenser in order to keep the condensate pump suction flooded at all times when it is in operation. This operating combination should be regarded as temporary and the main pumps should be secured as soon as the requirement for a larger quantity of feed has passed.

9560.308. DRAIN DISPOSAL

Ineffective deaeration of various drains is one of the major sources of oxygen contamination of boiler feed water in the feed systems preceding the pressure closed feed system. It will be noted from figure 9560-9 which applies to older ships, that the deaerating feed tank provides for complete deaeration of all drains. In general, drains having temperatures high enough to provide for flashing in the deaerating feed tank are led directly to the tank above the deaerating elements, while low temperature drains are led directly or indirectly to the main condensate line and discharged into the tank through the preheater spray nozzles. It is possible that, under certain conditions, flashing of high pressure drains in the tank may create pressures which will reduce the flow of steam through the atomizing valve, thus reducing the atomizing and scrubbing action necessary for complete deaeration. For this reason, on newer vessels, these high pressure, high-temperature drains are being discharged into the auxiliary steam line ahead of the deaerating tank so that they will combine with, rather than oppose, the heating and scrubbing steam.

9560.309. HIGH-PRESSURE DRAINS

High-pressure drains are collected in the high-pressure drain main and discharged directly to the deaerating feed tank in older vessels, and to the auxiliary steam line in newer vessels. Fuel oil heating drains are led to a drain-inspection tank similar to that provided in the vacuum closed feed system and are discharged from this tank to the deaerating feed tank.

9560.310. LOW-PRESSURE DRAINS

The low-pressure drain-collecting main is led to the fresh water drain-collecting tank which discharges to the condensers and is vented to the gland exhaust condenser. In some installations pumps are provided to discharge the drains collected in the fresh water drain-collecting tank directly to the main condensate line beyond the vent condenser. In this case, it is common practice to discharge heating system drains and evaporator first effect tube-nest drains to the fresh water drain-collecting tank instead of the main condensate line, as indicated in figure 9560-9. When the above pump is not provided, a heating system drain tank is usually installed and the evaporator first effect tube-nest drains are discharged by a pump located in the distilling plant compartment to the main condensate line.

9560.311. HEATING SYSTEM DRAIN TANK

The heating system drain tank is arranged to operate at subatmospheric pressure by provision of air ejectors with salt-water-cooled precoolers and after coolers. One or more automatically operated drain pumps are provided to handle the drains collected in the heating system drain tank. Use of the air ejectors maintains a vacuum on the drain tank and the heating system drain lines connected to it. This improves drainage of the heating system and eliminates noise and water hammer with consequent possibility of joint leaks at various points in the drain lines.

9560.312. RELATION TO SEMIENCLOSED SYSTEM

Operation of many units of the pressure closed feed system is generally similar to operation of similar units of the semienclosed system and reference should be made to articles in section II, part 3, describing operation of feed pump recirculating lines, thermostatic recirculation emergency feed pump, venting of shell and tube feed heaters, etc.

9560.313. MAINTENANCE OF DEAERATING FEED TANKS

1. The necessity for providing a continuing supply of oxygen-free feed water to steam boilers requires that the deaerating feed tanks operate effectively at all times. Effective operation of the tanks depends primarily on the operation of the spray valves. It is recommended that the spray valves be tested at least every 6 months. Other parts of the tanks, such as atomizing valves, if included in the tank design, should be examined at the same time.

2. A rig for testing spray valves is shown in figure 9560-12. All shore and afloat repair activities servicing ships equipped with deaerating feed tanks should construct this rig for periodic testing of spray valves. A water supply, with a minimum pressure of ten p.s.i. furnished either from shipboard or dockside, should be connected by a globe valve to the ½-inch I.P.S. nipple.

3. A 0-to-3 p.s.i. pressure gage or a 0-to-10 U-tube manometer containing mercury should be connected to the ¼-inch I.P.S. side outlet pressure tap. A ¼-inch valve should be attached to the ¼-inch I.P.S. drain connection on the bottom, if required.

4. Each spray valve can be tested and calibrated separately:

a. Mount the test rig, with its connecting water supply and indicating gage, in an angular position similar to that the spray valve occupies when actually installed in the deaerating feed tank.

b. Install the spray valve to be tested or calibrated on the 3-inch coupling on the test rig. A gasket of rubber or similar material can be used instead of a copper gasket for mounting the spray valve. If the 3-inch coupling has been threaded for a particular size spray valve, adapters can be fabricated for fitting other sizes of valves.

c. Fill the test rig with water, lifting the valve head either by hand or water pressure to remove air pockets.

d. Apply water pressure, slowly operating the water supply valve, to determine the condition of the valve seats and the pressure required to lift the valve head. Leaking evident during the build-up of pressure will indicate scored or poor seats. Record the pressure indicated when the valve opens. If the pressure does not agree with the opening pressure specified in the technical manual applicable to the tank being tested, the valve spring tensions should be adjusted. If the opening pressure is not given in the applicable manufacturer's technical manual, a pressure drop under test which produces the desired spray pattern should be noted. If there are seat leaks, the valves should be reseated before any final spring or lift adjustment is made.

5. When testing spray valves, the following items should be noted:

a. The valves must be completely open or shut. Leakage or dribble in the closed position indicates faulty operation which will critically affect deaeration. If such condition exists, the valves should be examined for scored or damaged seats or improper spring tension.

b. When the valve opens, the effluent should be a completely conical sheet of water. Any other form of discharge indicates faulty operation. An incomplete cone indicates cocking of the disk in respect to the seat. This may be caused by defective springs. Replacement valves should be examined carefully to see that the springs are correctly formed.

c. All valves in a particular tank should open at the same pressure differential across the valves to avoid leaving gaps in the total configuration. All associated valves should be adjusted for the same opening pressure.

d. Valve should operate freely in any position.

e. Valves and seats should be clean and free of any deposits.

6. Articles 9560.104 through 9560.107 describe the procedures for determining the dissolved oxygen concentration in the deaerating feed tank discharge. While this test is not definitive in the range of 0 to .02 p.p.m. of dissolved oxygen, it will serve to indicate major malfunctioning of the unit. For a more accurate determination of performance in the range of 0 to .02 p.p.m. with respect to the specification requirement of .014 p.p.m., all naval shipyards have personnel and facilities to perform the American Society for Testing and Materials referee method. For the results to be of value, all testing should be accomplished with samples from an operating deaerating feed tank feeding a steaming boiler.

9560.314. SUMMARY OF IMPORTANT OPERATING REQUIREMENTS

1. Keep internal steam check valve of deaerating feed tank in proper adjustment (article 9560.298).
2. Do not throttle steam inlet valves to deaerating feed tanks (article 9560.299).
3. Do not close nor throttle valves in vent line from operating deaerating feed tanks (article 9560.297).
4. Open feed pump recirculating lines whenever pumps are operating (articles 9560.256, 9560.312).
5. Never operate centrifugal feed pumps unless feed booster pumps are running (articles 9560.257, 9560.312).
6. Test feed heaters and relief valves to 1½ times the maximum working pressure after overhaul or repairs (articles 9560.230, 9560.231, 9560.312).
7. Secure starting-up line during normal operation of deaerating feed tank (article 9560.300).
8. Inspect for inoperative spray nozzles at frequent intervals (article 9560.313).

9560.315. CLEANING OF FEED AND CONDENSATE SYSTEMS

To reduce the possibility of contaminating boilers and steam generators it is necessary to maintain clean feed and condensate systems. Grease, oil, or other foreign matter in suspension in the water tends to produce priming, aid the various processes of corrosion, reduce efficiency and, if deposited on heating surfaces, may cause overheating and serious damage. To maintain clean feed and condensate systems the following are minimum guidelines that should be adhered to:

1. Inspect the feed and condensate systems regularly and when oil or dirt contamination is suspected. Should oil contamination occur, the source should be located and corrected, and the feed and condensate systems cleaned using the solutions specified in chapter 9510.87 and the procedures listed in chapter 9030.328-.334. The boiler should be cleaned in accordance with chapter 9510.87.

2. After periods of prolonged shutdown (6 weeks) the feed and condensate systems should be flushed in accordance with chapter 9030.330 and 9030.334.

3. After regular overhauls the feed and condensate systems should be cleaned in accordance with article 9560.315.1.

4. Prior to system flushes, temporary strainers should be installed in the suction side of the feed and condensate pumps. Strainers should be the inline, truncated cone type, 20 mesh or finer and of sufficient size to minimize pressure drop. The strainers should have a flange of suitable size to be bolted to the existing piping flange. Strainers must be removed after system cleanliness is established, and in any case prior to full power runs. Where strainers are installed a tag should be provided with the following instruction:

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INSTALLED REMOVE PRIOR TO
FULL POWER RUNS

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46.55. INSPECTION OF SPECIMEN TUBES

1. Specimen tubes shall not be drawn from a condenser or heat exchanger for examination except when specifically directed by the Bureau or a Board of Inspection and Survey, or under the following conditions:

a. When frequent leaks have resulted from tube failures, specimen tubes shall be drawn from widely separated parts of the unit in order to establish the general condition of the tubes.

b. When several tubes have failed in the vicinity of a steam or water inlet to the condenser shell, specimen tubes shall be drawn unless the cause of the failure can be determined by visual inspection of the steam side of the unit.

2. If either circumstance a. or b. above occurs, the Bureau should be advised on **Report of Equipment Failure** form NAVSHIPS 3621, with the following information being included:

a. The condenser involved and the last date when it was tubed or retubed.

b. Whether or not any of the tube leaks were caused by improperly expanded or packed tube joints.

c. The date when each leak occured, the type of tube failure (usually determined when failed tube is drawn and split for inspection), the conditions of operation, and any known or suspected contributory causes.

d. The source of supply of the tube, if known.

e. The position in the tube bundle of each failed tube and of each specimen tube drawn for inspection.

f. In what part of each specimen tube defects were found: external, internal, top, bottom, sides, ends, etc. To meet these requirements, tube ends must be marked before removal so that the top can be located.

g. Tube, tube sheet, and water box material and the type of tube joints employed.

h. How frequently zincs were renewed, description of condition of zincs, method of cleaning, and frequency of cleaning operations.

i. Method of cleaning tubes and frequency of cleaning operations.

j. Whether or not unit was kept thoroughly vented during operation.

k. Whether or not tubes were cleaned and blown out whenever sea water was drained from the unit.

l. What other corrective measures have been applied.

m. If severe deterioration of tube ends and tube sheets is visible and photographic equipment is available, photographs of the tube sheets should be taken and forwarded to the Bureau for information.

3. In cases where water chests are constructed of cast iron or steel and have not been given an initial protective coating on the salt water side, proceed as follows. The interior surfaces shall be thoroughly cleaned, preferably by abrasive blasting. When abrasive blasting is not practical, wire brushing, sanding or other suitable mechanical means should be used to remove dirt, followed by solvent cleaning to prepare as clean a surface as possible. After surface preparation, a coating system qualified under Class 1, 2, or 4 of Spec. MIL-P-23236 should be applied, as set forth in Chapter 9190.168, "Tank Coating Systems." The specific coating used should be recorded on the appropriate Machinery History Cards.

At each overhaul, iron or steel waterboxes should be inspected for condition of the protective coating. Former practice was to coat these boxes with Portland cement—in cases where such cement coating has begun to deteriorate it should be replaced entirely. Where a waterbox is coated in accordance with one of the above specification classes, deteriorated areas should be repaired in accordance with Chapter 9190.

4. In order that the required data may be readily available, a service history sheet should be kept for each condenser.

46.56. CARE OF WATER CHESTS

1. Most combatant vessel main condensers are fitted with monel metal (nickel-copper alloy) water chests. The interior surface of these water chests is wiped with a solder coating consisting of 2/3 lead and 1/3 tin, in order to prevent galvanic action which would otherwise occur between the bare monel surface and the tube and tube sheets in contact with the sea water. Care should be taken that this solder coating is maintained intact.

2. Most turbogenerator condensers and many auxiliary vessel main condensers are fitted with cast bronze water chests which normally require very little service upkeep except periodic washing of the interior surface to avoid deposit attack. If interior surfaces are coated with solder, the solder coating shall be maintained intact to avoid possible accelerated pitting where perforated.

3. In cases where water chests are constructed of cast iron or steel, the interior surfaces shall be thoroughly scaled and wire brushed and a good grade of Portland cement applied. The cement should be carefully sifted, using a fine mesh sieve, mixed to the consistency of heavy paint, and applied with a flat brush. Apply five coats, allowing each to dry before applying the next coat; then fill the seawater side of the condenser with clean cold sea water and allow the cement to harden for 24 hours. The cement wash should be applied to all iron or steel parts that are exposed to sea water. When overhauling the coating, do not remove the cement that is adhering properly. The coating should be inspected at frequent intervals and overhauled as necessary to maintain protection of the water boxes from corrosion. Approved cement-type paint or other protective coating may be substituted for the cement wash treatment specified above in cases where the alternate protective coating and method of application are specifically approved or specified by the Bureau in individual cases.

46.57. TEST FOR AIR LEAKS

1. As noted in article 46.25 constant vigilance must be maintained to detect and eliminate air leaks into the vacuum system. The most common causes of large air leaks into the vacuum system are loss of sealing steam pressure to the turbine glands, derangement of the float control dumping valve of the fresh water drain collecting tank, attempts to take on makeup feed from a dry reserve feed tank, or failure of steam supply to air ejectors.

2. Large air leaks into the vacuum system may be located by the use of a candle flame while the system is under vacuum, or by soapsuds applied to all possible points of leakage, with the condenser-shell subjected to a

five-pound air pressure. Small air leaks are most difficult to locate; they should be searched for, with the condenser and the connected piping which is normally under vacuum filled with fresh water, and with 5-10 p.s.i.g. air pressure in the turbine casing. Leakage of water obviously indicates location of an air leak. All places where it is possible for a leak to exist shall be investigated. Most condenser shells are provided with the following fittings or pipe connections, and joints should be examined as far back in the lines as vacuum exists under any operation conditions:

a. Shell relief valve.

b. Drain connections or plates at the bottom of the hot well.

c. Turbine drain lines.

d. Main exhaust flange and turbine exhaust trunk manholes.

e. Boiling out connection at bottom of shell.

f. Vacuum gage lines.

g. Thermometer connections.

h. Hot well gage glass and fittings.

i. Absolute pressure gage line.

j. Auxiliary exhaust dumping line.

k. Air ejector inter-condenser drain line.

l. Condensate pump suction line, vent line, and gland sealing system.

m. Air removal suction line.

n. Condensate recirculating line.

o. Makeup feed line.

p. Feed water heater drain line.

q. Evaporator drain line.

r. Drain collecting system drain line.

s. For vessels equipped with vacuum closed feed system (see chapter 56), all condensate and vent lines under vacuum connected to the surge tank should be tested.

3. Leaks at flanged joints and porous castings can usually be temporarily overcome by application of shellac where the condenser is under vacuum. Main exhaust trunk flanges are generally fitted with a flange grooving system in cases where the condenser supports the turbine, to provide for pressure pumping of suitable sealing compound. Most shell relief valves are fitted with a small gage glass to permit introduction of water above the valve disk as a test for tightness.

4. It is good practice to make the candle flame test consistently before getting underway and to make periodic applications of shellac to all joints. The candle flame test or an air test must be applied as soon as possible after it has been determined that excessive air leakage is present. (See art. 46.25.)

46.58. CLEANING STEAM SIDE OF CONDENSER

1. Grease or dirt on the steam side of a condenser is properly removed by boiling out with a strong solution of Navy standard boiler compound. (See Chapter 56.) Under normal conditions, condensers serving turbines should not require boiling out more frequently than every two or three years. Condensers serving engines may require boiling out operations much more frequently. (See art. 46.30.)

2. To boil out a condenser:

a. Drain and clean the sea water side.

b. Close condensate or air pump suction and other valves in lines connected to the condenser.

c. For each 1,000 gallons of water the steam side of the condenser will hold, make a mixture of 200 gallons of fresh water with 100 pounds of boiler compound. Dissolve the compound thoroughly in hot water (see chapter 56) and introduce the mixture into the condenser shell.

d. Fill the steam side of the condenser with fresh water to above the top row of tubes unless the water at this height, when brought to the boiling temperature, will overflow into the turbine exhaust trunk. In such cases the height will have to be regulated so that no overflow will take place or, preferably, the exhaust connection should be blanked off. It is desirable to circulate the solution during boiling, if practicable.

e. Introduce live steam into the condenser through the boiling out connection and bring the contents to the boiling point at atmospheric pressure. Care must be taken that the condenser is vented to the atmosphere during this operation and that no pressure is allowed to build up within the condenser shell.

f. Boil the solution for about 12 hours at the temperature given in e. above. Sufficient steam must be continuously introduced to assure that boiling of the solution is maintained. Vibration and noise resulting from admitting live steam to the condenser shell does not necessarily indicate that boiling of the solution is taking place.

g. Drain the condenser to the bilges or, preferably, pump the solution overboard if convenient means are available. Care must be exercised that none of the emulsion is admitted to the feed system.

h. Wash out the condenser several times with fresh water, follow by removal of an inspection plate near the bottom of the condenser and hose out all sediment collected in the bottom of the hot well.

i. Test the condenser for leaks.

j. Before and during this boiling out of a condenser, inspection shall be made by the officer in charge of the station of all boiling out and drainage arrangements to provide against accidents, and to see that proper safeguards are provided for the men engaged in this work. This is of particular importance if it should be impracticable to drain the solution through regular drainage connections to the bilges and should become necessary to drain the hot water and sludge contents by slackening away inspection handhole plates in the hot well. A safer method would be to pump out by use of a hose connection.

Part 4. Repair

46.71. RETUBING

The most common major repair required for the maintenance of condensers and heat exchangers consists of replacing the tubes.

46.72. REQUEST FOR RETUBING

1. The authority of the Bureau shall be obtained before the work of retubing a main propulsion condenser is undertaken. When a request for retubing is submitted, complete information shall be furnished as follows:

a. The advice required by article 46.55.2.

b. The extent of work considered necessary.

Partial retubing of a condenser is not normally desirable or economical, except that authority is sometimes granted for retubing one pass of a two-pass condenser.

c. Recommendation and comment by superior authority endorsing the request for retubing.

List of Effective Pages

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Change 2: 15 July 1966
Change 3: 15 October 1966
Change 4: 15 April 1967

NAVAL SHIPS TECHNICAL MANUAL
formerly
Bureau of Ships Technical Manual

This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of the Office of Chief of Naval Operations (CNO/ONI).

2. Cross connections between the potable-water systems and sea water, or other systems which are liable to contaminate the potable water, are not authorized.

3. Where it is necessary to use potable and sea water alternately, or supply potable water to machinery, the potable water shall be supplied through an air gap, to eliminate the possibility of contaminating the potable-water system. The arrangement of piping shall be such that a permanent connection cannot be made. Where this is not possible, hose connections and hose should be used and the hose fixed at the potable-water-supply end. The potable-water system should be protected against back-flow by the installation of a vacuum breaker/backflow preventer on the discharge side of the hose valve.

48.39. SEA WATER CONNECTIONS IN COMMISSARY SPACES

1. Sea water connections are not permitted in commissary spaces. There are certain conditions, however, where deviation from this practice has been made. These are:

a. Garbage grinders and food scrapers located in sculleries and galleys are supplied with fresh water, except that eductors are installed in the drain piping and the actuating water for these eductors is sea water. However, there are no sea water supply connections installed in these spaces.

b. In submarines where galley and mess spaces are in the same compartment as crew's living space, locked, closed-hose valves in the trim system are permitted to be used as fire plugs.

2. Only potable water shall be used for culinary work and for cleaning all messing equipment, including washing down of decks and bulkheads of any spaces where dishes or food containers are handled or stowed, and where food is stored, prepared, or handled in open containers.

48.40 POTABLE WATER SUPPLY FROM SHORE

♦ 1. In order to avoid taking on unsafe water when replenishing ships' potable water, it is imperative that the shore connection be made in accordance with local instructions on the use of shore connections. Shore station personnel should make all water connections between shore and ship. Ship's hoses should not be used for this purpose where hose is provided by the shore facility. Before connecting shore hose to the ship's filling connection the ship's crew should thoroughly swab the cap threads. The interior surface of the filling connection valve also should be swabbed back to the valve closure. The swabbing solution should contain not less than 100 ppm of chlorine.

2. Where emergency dictates the use of ship's potable water hose, connect the hose as indicated above and flush for 30 to 60 seconds before connection is made to shore facilities. Where the potable water hose is provided by the shore facility the ship's force should insist that the hose be flushed for 30 to 60 seconds before connection is made to the ship's potable water system.

3. If for any reason contamination of the ship's hoses is suspected, either because of careless handling, dropping into harbor water, or not capped or plugged during storage, the hose shall be disinfected. This should be accomplished by first thoroughly flushing the hose with potable water for 30 to 60 seconds, then subjecting the interior to a chlorine solution containing a minimum of 100 ppm of chlorine for at least two minutes, followed by flushing with potable water for 30 to 60 seconds. The hose fittings and connections should be immersed in a chlorine solution of at least 100 ppm before being connected. ←

4. For complete instructions covering potable water supply, including disinfection, testing, tank disinfection, and hose handling see **Manual of Naval Preventive Medicine** (NAVMED P-5010-6).

48.41. HOT FRESH WATER

Hot water normally is supplied from small-hot-water groups served by individual heaters. A small circulator is sometimes provided to maintain hot water at the system outlets. Where the hot water is used for lavatories and showers, the heater temperature controls should not be set over 130° F.

48.42. DECONTAMINATION SHOWERS

1. All fresh-water-shower spaces on the main deck and below are designated as decontamination stations. Where showers do not exist on the main deck or below, shower spaces above the main deck are designated as decontamination stations.

2. A separate egress and ingress, located to minimize interference between incoming and outgoing traffic, is provided for all decontamination stations where practical, and where no loss of sanitary facilities or berthing accommodations will result.

3. In addition to the above, salt-water showers supplied from the flushing system are provided in washrooms, below the main deck and are designated as fresh and salt water decontamination stations. Large aircraft carriers have four fresh and salt decontamination stations, battleships have three stations, cruisers and escort carriers have two stations, and destroyers, auxiliaries, and other surface types have one station, or two stations where practicable.

4. One salt-water nozzle is provided in the overhead of each shower stall in all fresh and salt water decontamination stations. Piping for salt-water-shower heads are sized to provide a minimum pressure of 25 psi at the most remote shower head, while discharging 10 gpm through each shower head.

5. A label plate inscribed "SALT WATER-NOT TO BE USED FOR GENERAL PURPOSE SHOWERING AND NEVER USED IN POLLUTED WATERS" is provided on the flushing-out valve to the salt-water-decontamination showers. Individual control valves are not required for these showers.

48.43. PLUMBING SYSTEM DRAINAGE

1. Plumbing drainage systems are arranged so as not to impair the watertight integrity of the vessel. Drainage systems serving more than one watertight compartment have ♦ roundway plug cocks installed to prevent intercompartment flooding when the ship is in damaged condition.

2. The bulkhead deck is defined as the highest deck to which watertight bulkheads extend and are made effective.

Deck drain valves are provided only for deck drains below the bulkhead deck except where a vital space is located on the bulkhead deck; deck drains serving that space shall be provided with valves. Deck drain valves normally are kept open and are to be closed for damage control purposes. Deck drains are to be considered waste drains and should not be connected to soil drains. Deck drains connected to the plumbing system always should be provided with at least a 2-inch water seal trap.

3. Overboard discharges from plumbing systems always should be provided with positive closure valves at the shell of the ship. Where the overboard discharge is above the waterline, these closures should be of the gag-scupper type and the valve should be installed so that the flap swings in a fore and aft direction so as not to swing open with the roll of the ship. Where overboard discharge from plumbing systems is below the waterline, the closure should be accomplished by the installation of a roundway plug cock backed up by a swing check valve. The check valve should be installed so that the valve body is horizontal and the flap swings in a fore and aft direction.

4. Backflow can be caused by the roll of the ship causing reversal of flow in long athwartship runs. Where rearrangement of piping is not feasible, a vent installed at each end of the athwartship run will minimize the effect of the backflow or blow back. The installation of check valves to remedy these conditions should be avoided where possible since such valves in soil and shower drains require a great deal of maintenance to keep them free of paper, hair, and other debris.

5. Air-pressure-pipeline cleaners can be used to clear debris from piping and plumbing fixtures. Air impact and constant-pressure types are available. The air-impact type (stock No. G4940-204-3738) clears debris through the quick release of compressed air hand pumped into a compression chamber. The constant-pressure type (stock no. G4940-293-8413) is designed to use 100 psi air to clear the piping.

48.44. COMBINING DRAINS

1. Soil drains such as those from water closets and urinals should not be combined with drains from showers, lavatories, and sinks, except at a common overboard discharge, provided that each of the mains has a positive closure of the gag-scupper type.

2. No waste pipe or drain from any of the following equipment shall be connected directly to a plumbing drain; where such equipment is drained into a plumbing or deck drain, an air gap shall be provided.

a. Refrigerator, steam table, or other receptacle where food is stored.

b. Any appliance, device, or apparatus used in the preparation of food or drink.

c. Any appliance, device, or apparatus using fresh water as a cooling or heating medium.

d. Sterilizer, water still, fresh water treatment device, or potable-water-operated device.

48.45. PLUMBING VENTS

♦ 1. All plumbing fixtures connected to the plumbing system should have standard traps, the water seals of which are 2 to 4 inches in depth. Such traps must be adequately vented to drain properly and to prevent siphoning of the traps. Each fixture trap should be served by a vent located so that the total pitch of the fixture drain, from the trap weir to the vent opening, is not more than one inside diameter of the fixture drain pipe. Where a stack vent meets the above requirements, individual back venting is not required. The developed length of the fixture drain line between the trap weir and the vent connection should be not less than 2 nor more than 48 pipe diameters. All vertical drains should be stack vented from the highest point. Typical fixture piping and venting is indicated on BUSHIPS Mechanical Standard Drawings Numbers 810-1385920 to 810-1385923 inclusive. In order to reduce the number of penetrations to the weather, vents should be combined insofar as practical. Waste vents and soil vents may be combined above the highest soil fixture in the system.

2. Winds of high velocity tend to blow into or pass across the vent openings. This wind action causes loss of seals or blow back of odors through the traps because of the resulting increase or decrease of air pressure within the vents and plumbing system. This is an inherent characteristic which can be almost completely overcome by fitting half round shields or tees at the open end of the vent. The run of the shields or tees should be vertical rather than horizontal as has been past practice.

48.46. AIR CHAMBERS

Air chambers are provided, as necessary, to prevent water hammer at the tops of risers, the ends of horizontal runs, and at spring-closing valves and flush valves in hot and cold fresh water and salt water supply piping to plumbing fixtures or groups of plumbing fixtures, such as lavatories, urinals, and water closets. Periodically, or when water hammer is evident, these air chambers should be replenished with air by closing the supply cut-off valves and bleeding the systems at their lowest outlets, with the petcock at the top of each air chamber opened for venting and complete drainage. When the systems are completely drained, the petcocks and fixture outlets should be closed and the cut-off valves opened. The resulting trapped air in the air chambers will act as a cushion to minimize water hammer in the plumbing-supply systems.

48.47. FRESH WATER FLOW BALANCING

Loose key, lock shield, or screwdriver-operated valves are generally installed in supply lines to individual plumbing fixtures. These valves are for balancing the flow in the system so that the fixture most remote from the pump will be adequately served as well as those near the pump. These valves require regulation to provide a well balanced system. Where repairs to faucets are necessary, the above valves may be shut off to isolote any particular foucet or faucets from the rest of the supply system.

Type	Flow	Length	Fed. Stock Number
Coalescer	Inside to out	20-inch	HF4330-542-5719
Coalescer	Inside to out	24-inch	HF4330-542-5720
Coalescer	Outside to in	24-inch	HF4330-609-6871
Separator	Outside to in	17½-inch	HF4330-542-5722
Separator	Outside to in	24-inch	HF4330-542-5721

6. New coalescer elements sholl be tested prior to installing them in the filter. Elements, regardless of whether the normal direction of flow is from the inside to outside, or from the outside to the inside shall be tested as follows:

a. **Equipment required:** The testing equipment consists of an open tank for JP-5 and water, pump, flow meter, pressure gage, piping or flexible hose, element-mounting fixture, valve, and the elements to be tested, arranged as shown in figure 48-16. Good illumination of test rig is required.

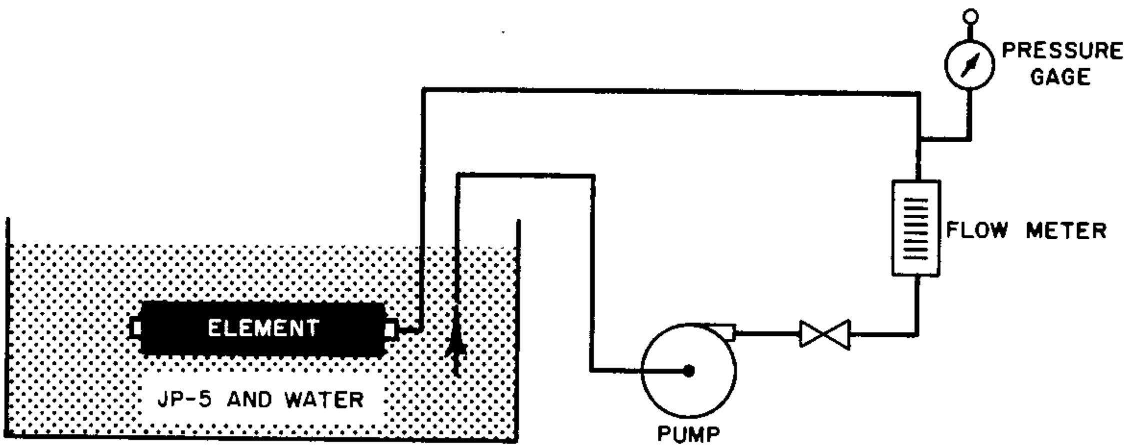

Figure 48-16. Coalescer Element Test Equipment

b. **Method:** The inspection test shall be conducted as follows:

(1) Fill tank with 9 parts JP-5 and 1 part of fresh water.

(2) Submerge mounted coalescer element in tank.

(3) Start pump with valve slightly cracked open to give a small fuel flow through element.

(4) Increase flow rate to 10-g.p.m. maximum (the pressure will be about 3 to 5 p.s.i.); adjust depth of suction so that a mixture of water and fuel is pumped; continue pumping until all air is expelled from the element. Air in the element is indicated by air bubbles issuing from the outside of the element and rising to the surface of the fuel in the tank.

(5) Keep the element submerged and rotate it to observe whether the element is good or defective. If the element is good and functioning properly as a coalescer, droplets of **clear** water will form on the outside surface of the element and then drop off and fall to the bottom of the tank. If the element has defects such as inadequate internal seals or broken paper or fiberglass, the element will not coalesce properly. This condition will be indicated by one or more cloudy streams of uncoalesced water issuing from the element.

7. New separator elements shall be tested prior to installing them in the filter. Elements shall be tested as follows:

a. **Equipment required:** The testing equipment consists of an open tank for JP-5, water manometer, element-mounting fixture, flexible tubing, and the elements to be tested, arranged as shown in figure 48-17. The air flow will be from inside to outside, which is opposite to the normal direction of fuel flow. (If a water manometer is not available, one can be improvised with glass tubing, rubber tubing, and a board. Glass tubing is readily available from the Medical Department.) A small tee (aircraft fitting) is also required. Air pressure can best be applied by the mouth or hand aspirator. Good illumination of the test rig is required.

b. **Method:** The inspection test shall be conducted as follows:

(1) Fill the tank with clean, dry (water free), JP-5 fuel.

(2) Submerge mounted-separator element in tank in a horozontial position so that the upper surface is about 2 inches below the fuel surface.

(3) Blow air into element until 6 inches of water pressure is reached. Rotate element and observe for air bubbles escaping element in a stream.

(4) If no bubbles occur as in (3) above, gradually increase air pressure until air bubbles suddenly break through all over.

c. If the element is good and there are no breaks or holes and all seals are adequate, there will be no streams of air bubbles up to the sudden breakthrough of very fine air bubbles, causing a foamy condition on the fuel surface. CAUTION: When the element is first submerged, and a very low air pressure is applied, there may be a few air bubbles due to air trapped between the element and its perforated container. These should be disregarded. If the element has defects such as breaks or holes or inadequate seals, a steady stream of air bubbles will issue from the defective points in the element at 6 inches of water-air pressure.

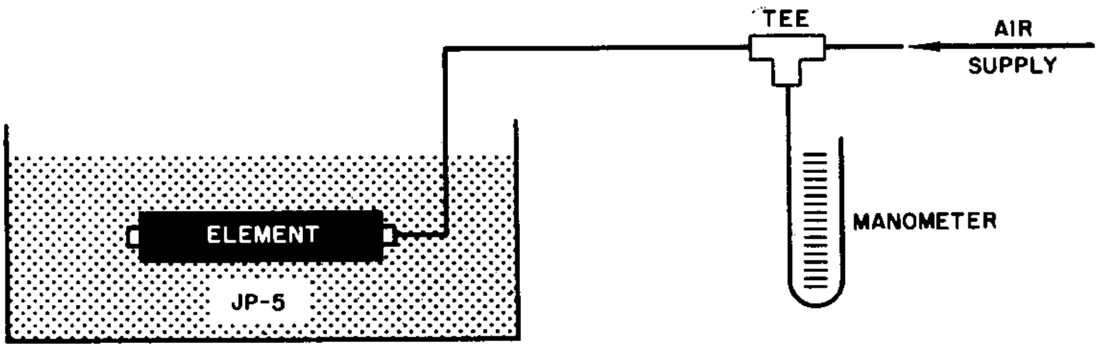

Figure 48-17. Separator Element Test Equipment

8. Test of filter automatic devices: Filter-automatic-water drain and slug-control valves derive their operating pressures from the pressure of the fuel within the filter case. If the actuating-line strainer becomes clogged with solids, it is possible to discharge fuel through the drain and/or pump water through the filter. This strainer, if external to the filter case, should be cleaned monthly. If internal, it should be cleaned when the case is opened for element replacement. These controls should be checked for proper operation monthly. The only known means of checking their operation is to actually introduce clean salt water into the filter and observe the opening of the automatic-water-drain valve and the closing of the slug-control valve at the filter discharge.

a. **Transfer Filters**

The water may be introduced through any connection to the filter inlet. As all filters have a flanged-pressure-gage-line connection at the filter inlet, this location is recommended. Fit a tee to the flange, reconnect the gage line to one branch, and attach a valve and hose connection to the other branch. With the filter in operation, reduce the inlet pressure by throttling to at least 25-p.s.i. below the available water pressure. Attach a water hose and slowly add clean salt woter until the automatic-woter-drain valve opens or the water level reaches the top of the water-sump-gage glass.
If the drain valve fails to open, secure the filter and determine the cause. If the drain valve operates properly, adjust the water-flow rate so that the drain valve opens about once a minute. Continue testing for at least five minutes. Take samples of fuel from the filter-fuel discharge, in glass containers, and observe their appearance. If the fuel is cloudy or visible water is present, the coalescer elements should be replaced and separator elements tested and replaced if defective or if dirty. Without changing the water-flow rate, manually close off the water-drain line so that no water can drain from the sump. If the automatic-slug-control valve at the filter discharge does not close within three minutes, or water level posses the top of the water-sump-gage glass, secure the filter and determine the cause.

b. **Service Filters**

The service-filter-automatic-water drain and slug-control valves shall be tested monthly in the same manner as for the transfer filters, except that water shall be injected through the steaming-out-connection at the filter inlet.

SECTION VI

Part 4. Meters

48.138. REMOVAL OF AIR AND GAS FROM LIQUID

Air and gas should be removed from the liquid being measured before reaching the meter, otherwise the meter will register their passage.

48.139. CLEAN STRAINERS

When strainers are fitted, they should be cleaned as required by the nature of service rendered by the meter.

48.140. ALLOWABLE ERROR OF METER

All meters, except fuel-oil meters, are considered satisfactory if they show errors of not more than plus or minus 3 percent. Fueling fuel-oil meters should show an error of not more than 3 percent.

48.141. TEMPERATURE REQUIREMENTS

1. The ordinary cold-water meter has certain hard-rubber parts which will be ruined by distortion if subjected to temperatures above 100° F.

2. A hot-water meter will operate satisfactorily at temperatures usually experienced when handling hot or cold water.

48.142. METER SPECIFICATIONS

To obtain best results from a meter, one should be installed with a capacity in proportion to the flow to be measured, rather than one of the same size as the piping in which it is to be installed. The safe-maximum capacity of any particular size of meter depends upon the type, and can be obtained from the specifications, or from the Bureau of Ships.

48.143. PRECAUTIONS TO PREVENT WEAR

To prevent rapid wear in a meter, it never should be operated at its maximum capacity for prolonged periods of continuous flow. For continuous operation, the rate of flow recommended by several manufacturers varies from one-tenth to one-half of the maximum capacity. When operating at capacities less than 5 percent of maximum, many meters are

CHANGE 4
15 April 1967

Chapter 60

Electric Plant–General

List of Effective Pages

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24–46	Original
47	Change 1
48–93	Original

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stator windings rated at 2,000 volts or more but should not be used on circuits or equipment rated at lower voltage.

(2) **Duration of test voltage application.** When the test voltage is initially applied, the insulation resistance will gradually increase for an appreciable period of time, particularly in long cable runs and large machines. In short cable runs and machines below 1,000 kilowatts, this effect is not so pronounced. When making measurements, the test voltage should be applied until a constant reading is obtained. Hand-driven generator type instruments should be cranked for at least 30 seconds to ensure a steady reading. In cases where it is impossible to crank the instrument until a steady reading is obtained, it should be turned as long as practical and subsequent tests made for the same length of time so that the readings will be comparable.

(3) **Residual charge.** Residual charges retained in insulation affect the readings of insulation resistance, especially in large machines and long cable runs. When measuring the insulation resistance of machines above 500-kilowatt capacity, it is recommended that the conductors be grounded and discharged for a few minutes prior to the measurements. A short length of cable with clips attached at each end will be found convenient for this purpose. Separate circuits may be discharged simultaneously by connecting all circuits together and to ground. Personnel should exercise caution against the possibility of receiving shock due to contacting windings before they have been discharged. This applies especially to large a-c propulsion generators and motors.

Part 3. Cable Insulation Resistance

60–111. FACTORS AFFECTING INSULATION RESISTANCE

The primary purpose of making insulation resistance measurements of shipboard cable installations is to determine the condition of the cable in order that deterioration and incipient failure may be discovered and remedied. However, in order to arrive at a reliable conclusion regarding the condition of the cable, it is necessary to evaluate each of the following factors, which have a significant effect on insulation resistance measurements in addition to the condition of the cable:

1. **Other apparatus connected in the circuit.** A true conclusion regarding the cable condition cannot be reached if other equipment is connected in the circuit when the measurement is made. For example, when measuring the insulation resistance of the positive cable connecting a generator to a switchboard, the cable should be disconnected at each end. If this is not done, the measurement will include the insulation resistance of the bus work, all apparatus connected to the bus, the generator, and the negative cable. Since the insulation resistance of this other apparatus is in parallel with that of the cable, the measured value of the combination may be considerably lower than that obtained if the cable is disconnected and measured separately. See article 60-92 (2). For convenience it may be desirable to make initial measurements with the cable only partially isolated by opening the switches, circuit breakers, or other disconnecting devices provided in the circuit. If such measurements indicate resistances which are satisfactory when compared with previous values or with limiting values, no further isolation of the cables may be necessary, but if the resistances are low in comparison with the desired standard, it will be necessary to disconnect the cable completely and measure it alone before concluding that the cable is responsible for the condition. In all cases, when making measurements, it is important to record the exact amount of other equipment included in the circuit in order to make significant comparisons with similar past or furture measurements.

2. **Total quantity (number and length) of cable measured.** The insulation resistance varies inversely as the total length of the cable. The insulation resistance of a length of cable is the resultant of a number of small individual leakage paths or resistances distributed along the cable and connected between the conductor and the cable sheath. Assume, for example, that one of these leakage paths exists in each foot of cable. Then in 10 feet of cable there would be 10 such paths for current to flow between the conductor and the sheath, and the total amount of current flowing in all of them would be 10 times as great as that which would flow if the cable were only 1 foot long. In other words, the longer the cable the more leakage paths exist and hence the lower the insulation resistance. In order to have a common unit of comparison, cable-insulation resistance should be expressed in megohms (or ohms) per foot of length. This is determined by multiplying the measured insulation resistance of the cable by its total length in feet. The total length is determined as follows:

a. For single conductor cable the total length is equal to the length of the cable sheath.

b. For multiple conductor cable, the total length depends partly on how the conductors are used in the circuit while the measurements are being taken. If the cable is isolated from all equipment or goes from switch to switch, the total length is equal to the length of the cable sheath. As an example, take a type TSGA cable which has a cable sheath length of 300 feet and in which the three conductors are phases A, B, and C of a three-phase power circuit. The total length of cable to be used in converting measured insulation resistance to insulation resistance per foot is 300 feet, not three times 300 feet. The reason for this is that each conductor is measured separately. If this cable is connected, either in series or in parallel, to a similar cable which has a sheath length of 300 feet, the total length is 600 feet. As another example, the total length of 300 feet of type MSCA-7 (7-conductor cable) is 300 feet, not 7 times 300 feet; and 300 feet of type MSCA-7 connected to 300 feet of type MSCA-2A represents a total cable length of 600 feet. If the cable is connected to a three phase device or single phase devices on each phase, the leakage paths are all in parallel and the total cable length now will be the number of conductors times the sheath length.

c. For multiple conductor degaussing coil cable, the total length is the length of the conductors, which is the length of the cable sheath times the numbers of conductors. This is because degaussing cable is installed in the form of a loop and the conductors in multiple conductor cable are connected in series where the ends of the cable meet to make a single coil with as many turns as there are conductors in the cable. As an example, take a 19-conductor MDU cable with a cable sheath length of 500 feet. The total length to be used in converting measured insulation resistance to insulation resistance per foot is 500X19 = 9,500 feet.

(3) **Type of cable.** Insulation resistance varies considerably with the nature of the insulating material employed and the construction of the cable. It is therefore, possible to judge the condition of a cable as determined by its measured insulation resistance only when considered in relation to the typical characteristics of the particular type of cable. Figures 60-5 and 60-7 provide means for determining if the measured insulation resistance values are above the minimum acceptable values. Figure 60-7 is applicable to cables listed in the figure but not to large single conductor propulsion power cables. Figure 60-5 is applicable to large single conductor propulsion power cables. Points 1, 2 and 3 of Figure 60-7 cover Types SGA, HF, DG and SCA cables at temperatures of 140° F, 70° F and 40° F respectively while points 4, 5, and 6 cover telephone cables of Types TTHFA and TTHFWA at these same temperatures. It should be noted that these temperatures are assumed ambient temperatures, not that of the sheath as was previously used in measuring insulation resistance of power and lighting cables. The type SHFA, SHFL and SSGA large propulsion power cables resistance vs temperature characteristics illustrated in Figure 60-5 show that a resistance change of about 3000 to 1 may occur in the normal operating temperature range as measured at the cable sheath. The cable sheath temperature shall be considered in conjunction with the insulation resistance measurements of large single conductor propulsion cables. For large single conductor propulsion power cables, the cable sheath temperatures may normally be estimated from past experience with sufficient accuracy to determine that the cables are in satisfactory condition. If the results obtained by estimating the temperature indicate values of insulation resistance approaching the limiting values indicated on the curve, temperature measurements of the cable should be made. Fairly accurate measurements of the temperature of the sheath of the cable must be made to permit a reliable interpretation of the insulation resistance of propulsion power cables and proper use of Figure 60-5. The temperature should be measured by means of thermometers attached to the cable sheath or armor at several points along the length of the cable and these values averaged. The thermometer bulb should be placed in direct contact with the sheath or armor, scraping away the paint at the point of contact and holding the thermometer in place by pads of felt or other heat-insulating material placed over the bulb and secured with tape. The number of thermometers used and their location should be such that they indicate a representative average of the sheath temperature of the entire cable being measured.

60-112. BASIS OF ACCEPTANCE

1. The insulation resistance values for each complete power circuit shall be at least one megohm and for each complete lighting circuit shall be at least 0.5 megohm. If the values are below these minimums, corrective action shall be taken.

2. If successive isolation of components from the circuit indicates that the low insulation resistance is due to the cables, the acceptance values which shall be used to judge whether or not a cable is safe to operate depend upon the temperature, the cable length, and the type of cable. Measurements shall be made either immediately upon deenergizing circuits which have been energized for at least four hours, or after the circuits have been deenergized for at least four hours. Circuits which have been deenergized for at least four hours shall be classed as either in a warm ambient or in a cold ambient. A warm ambient is defined as a warm climate or a condition in which the entire cable is in a heated space and not in contact with the ship's hull. A cold ambient is defined as a cold climate or a condition in which most of the cable is in an unheated space or is against the ship's hull in cold waters. The cable temperture shall be considered to be 104° F. if the cable has been energized for four hours, 70° F. if it is deenergized in a warm ambient, and 40° F. if it is deenergized in a cold ambient. On the bottom of figure 60-1b, select the point **of allowable resistance per foot based on the ambient con-**dition and the type of cable. Using the nomograph, a straight line from the measured insulation resistance to the length of cable should cross the resistance per foot line above the selected minimum resistance per foot point. Corrective action is required if the resistance per foot is less than the selected point.

3. For degaussing cables, if the insulation resistance is less than 0.1 megohm, corrective action shall be taken.

4. If lower values for particular circuits have previously been determined to be satisfactory, (see article 60-113 (3) (a) also) these shall be considered the minimum acceptable values.

5. For propulsion power cables, the values given in the curve in figure 60-5 shall be used to indicate the necessity for corrective action.

60-113. PROCEDURE FOR DETERMINING INSULATION RESISTANCE

In accordance with the foregoing discussion, the following procedure is recommended for determining the insulation resistance of power, lighting, and degaussing circuits (see chapter 9410, sec. IV for measurement of insulation resistance of electric propulsion installations and chapter 9650 for measurement of insulation resistance of interior communication and fire control circuits):

(1) In order to avoid unnecessarily disconnecting apparatus with resultant time, labor, and possible damage to cables by handling, approximate checks of insulation resistance of complete circuits should be conducted. For this purpose, the "circuit" should include the installed components of the circuit; viz., conductors in the cable or cables,

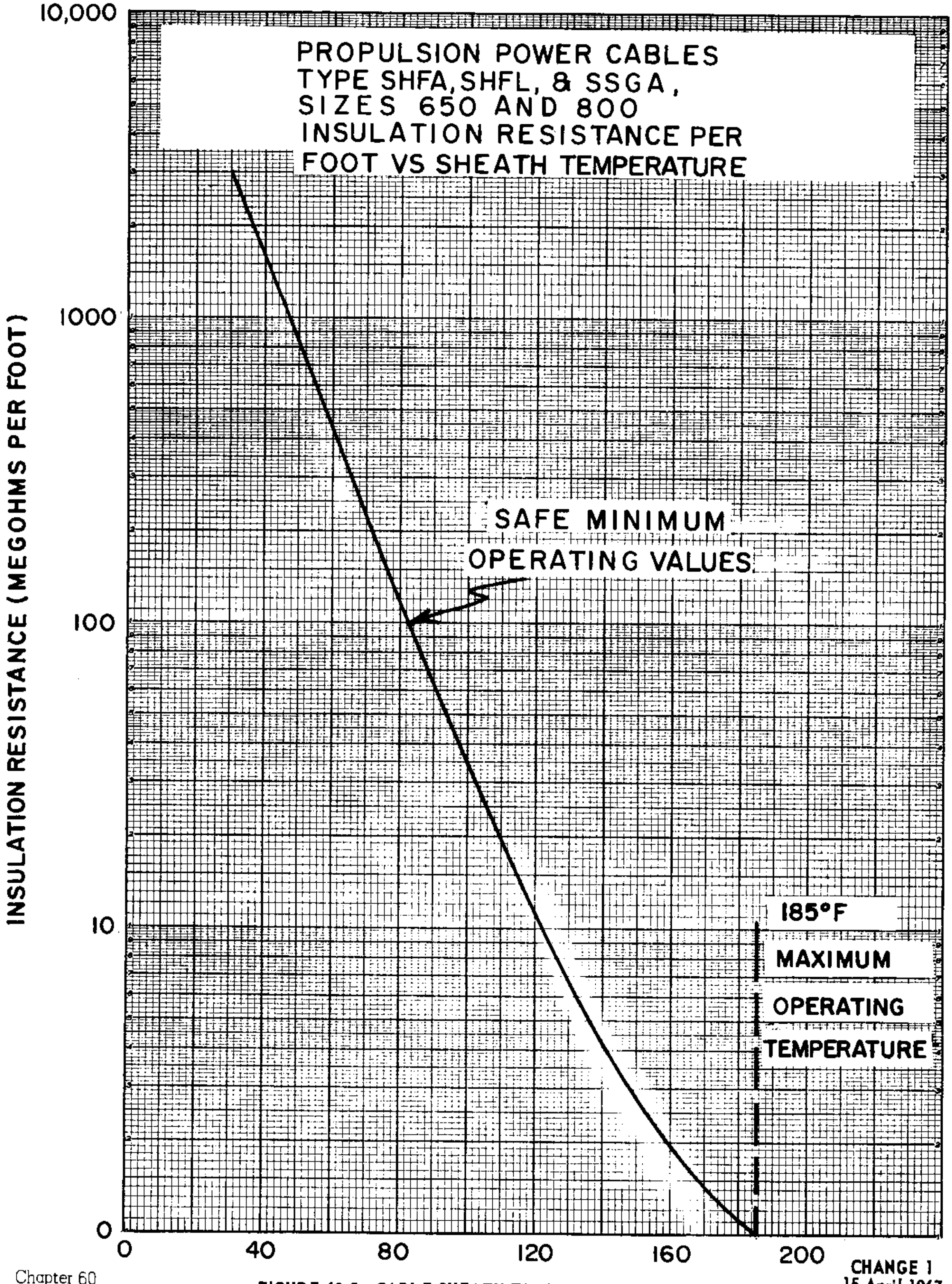


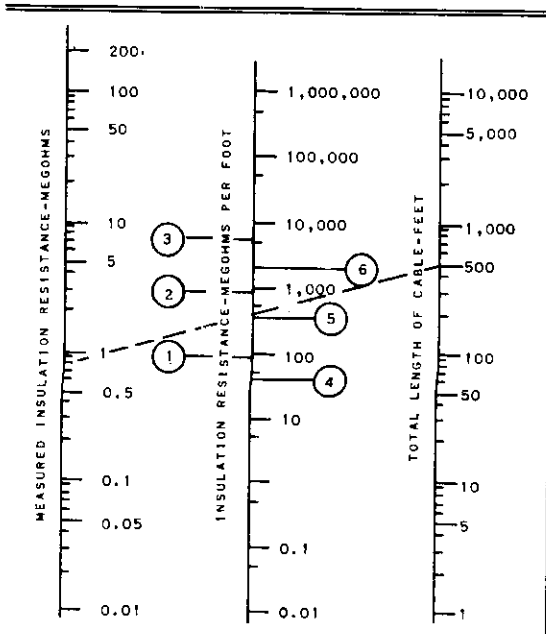
FIGURE 60-5. CABLE SHEATH TEMPERATURE (DEGREES F)

INDEX	CIRCUIT	LENGTH	CARD NO.

DATE (MO, DA, YR)	MEASURED RE-SISTANCE MEGS.	RESISTANCE PER FOOT (CABLE) MEGOHMS	AMBIENT TEMP.-ASSUMED (104°F), 70°F, OR 40°F)	REMARKS
	A B C			
	A B C			
	A B C			
	A B C			
	A B C			
	A B C			
	A B C			
	A B C			

RESISTANCE TEST RECORD CARD NAVSHIPS 531-1 (10-63) (FRONT)

Figure 60-6



NOMOGRAPH FOR OBTAINING RESISTANCE PER. FT.

OBTAINING RESISTANCE PER FOOT - *Example*

Line is drawn on nomograph from 0.8 megohms (measured) to 500 feet (length of cable per card or plans). If points ①, ④, or ⑤ apply, cable is O.K. If points ②, ③, or ⑥ apply, cable may be in poor condition - investigate further.

MINIMUM ALLOWABLE INSULATION RESISTANCE CABLES (MEGOHMS/FT)

	TYPE OF CABLE	
	SGA, HF, DG, SCA	TTHFA, TTHFWA
JUST AFTER SHUTDOWN 104°F	95 (POINT ①)	40 (POINT ④)
↓ EQUIPMENT SECURED 4 OR MORE HOURS		
WARM CLIMATE SUMMER OR ALL IN HEATED SPACE 70°F	920 (POINT ②)	380 (POINT ⑤)
COLD CLIMATE WINTER OR AGAINST COLD HULL 40°F	5500 (POINT ③)	2200 (POINT ⑥)

RESISTANCE TEST RECORD CARD NAVSHIPS 531-1 (10-63) (REVERSE) C-33954

Figure 60-7

the permissible limits of figure 60-6, the cable is unsatisfactory and should be replaced.

(4) Judgment should be exercised in the replacement of cables showing marginal values of insulation resistance, particularly those cables where the insulation resistance measurements do not indicate a continuing downward trend, and have remained fairly constant (or show an upward trend) over a period of time with readings in a range below or near the limits of figure 60-5 and 60-7, since in most such cases actual break-down of the insulation is not probable, and the cable may be continued in service without failure. The limits of figure 60-7, were established arbitrarily with what was considered to be an adequate factor of safety. It **is, therefore, quite possible for cable to continue in service without failure with values of insulation resistance** below these limits.

60-267. SPLICES

Cable splices should not be made by ship's personnel except as an emergency repair. Where such splices have been made they should be replaced at the earliest opportunity by a continuous length of cable or by an approved splice installed by a repair activity. The repair activity will determine which procedure should apply. Repair activities have the necessary facilities, materials, and knowledge for making approved splices in accordance with a standardized method. Such splices are permitted only on a limited basis where it has been determined by the inspection activity that time and replacement cost for a new cable is excessive and the existing cable is in good mechanical and electrical condition.

60-268. DEAD-ENDED CABLES

Dead-ended cables result from alterations made when time does not permit removal or when removal of cable may result in damage to other cables. They involve substantial increases in dead weight, frequently at high levels, lower damage resistance and increase the difficulty of cable identification, removal, maintenance, and alteration. They should be located and identified, and removed at the first opportunity, if such removal can be accomplished without damage to other cable in vicinity.

60-269. CABLE FITTINGS

(1) ***Stuffing tubes.*** The watertightness of stuffing tubes used with Navy shipboard cables involves several factors which must be considered in connection with their maintenance. Unlike piping and shafting, electric cables are resilient, cannot withstand high packing pressures, and are used with specially designed stuffing tubes and packings which employ moderate pressures and obtain a seal chiefly because of the plastic nature of the sealing compound. Even with these packings, loose seals occasionally develop due to any one or more of several factors, such as loosening of the gland nuts, flowing of the intermediate or soft "B" packing, or "necking" of the cables. However, there is only a remote chance of the gland nuts loosening or backing off after the compartment in which they are located has been painted, since the paint over the gland nuts will tend to keep them from turning. Loosening of the seal is more often caused by flow of the soft plastic packing into the interstices of the cable armor, or by depression or "necking" of the cable itself because of excessive packing pressure. Continued setting up or tightening of stuffing tube gland nuts beyond that required to maintain watertightness is undesirable since with each setting up and equalization of pressure further "necking" of the cable occurs. Moreover, successive tightening of gland nuts may cause a lowering of the cable insulation resistance due to compression of insulation near the stuffing tubes and if carried to excess, may ultimately damage the cable sheath. It is, therefore, necessary that care be taken when setting up gland nuts to avoid excessive packing pressure.

This is particularly important for stuffing tubes which are periodically or continuously exposed to high temperatures because high temperatures soften the cable sheath and increase the likelihood of cable "necking." When making periodic compartment air tests on shipboard (see ch. 29), it is preferable that no stuffing tube gland nuts be tightened except those which have obviously loosened or backed off, or unless the air test shows leakage through the stuffing tubes. When stuffing tube gland nuts must be tightened, an additional turn of soft packing should be inserted if it is at all practicable. Careful observance of this procedure should result in satisfactory watertightness of the stuffing tubes without impairing the performance of the cable.

(2) ***Hangers.*** The bolts and nuts which secure cable hangers, connection boxes, and wiring appliances to bulkheads and other supports may be loosened and lost because of vibration. Since loose electrical equipment is a hazard to personnel as well as costly in material maintenance, all hands should be trained in recognizing and reporting such conditions on a continuing basis so that maintenance measures will be taken.

(3) ***End seals.*** The heat and flame resistant cables used on shipboard have a watertight sheath to keep water from reaching the electrical insulation. Casualty reports show that this sheath can serve as a conduit in carrying considerable quantities of water from a flooded to an unflooded space. Water which enters the sheath through a puncture or through an open cable end in the flooded space travels through the interstices between the strands of the conductors because of the head pressure set up in the flooded space. At the far end of the cable, the discharged water may cause short circuits or grounds in the equipment to which the cable is connected. There is, therefore, a definite possibility that flooding of one compartment may result in extensive damage to electrical equipment in other compartments. This has occurred in a number of instances. To prevent future recurrence of this trouble, cable ends are sealed where necessary to prevent the entrances and discharge of water from cable ends. Additional cables believed to require this protection should be reported for investigation and correction during overhaul periods. Great care should be exercised when working around cables and switchboards to prevent damage to the cable end seals, and frequent inspections should be made for visual evidence of defects in the seals. If any holes are found in the synthetic tubing used at end seals, a ***temporary*** repair should be made by wrapping the tubing tightly with several layers of synthetic tape, half lapped, and serving with cord over the tape. Other defects which may be noted should be repaired as effectively as available materials and equipment permit. All cable end seals to which temporary repairs have been made should

be tagged and scheduled for permanent repair at a naval shipyard or shore base at the earliest opportunity. Currently manufactured cables are required to have an impregnant between the strands and in the material between the conductors and the inside of the sheath. This practice has resulted in a material decrease in the amount of water that can flow through a cable but has not accomplished complete watertightness. Cable end sealing is still required for these newer cables.

60-270. CABLE MARKING TAGS

(1) All permanently installed ship's cables are identified by metal tags upon which the cable designation is embossed so that the cables may be readily identified for purposes of maintenance and replacement. Past practice was to use the color of the cable tag to give coble classification. This practice has been discontinued but colored cable tags will still be found on many ships.

(2) The letters which have been used in the past to designate cables for different services are as follows:

C-Interior communication.
D-Degaussing.
F-Ship's service lighting and general power.
FB-Battle power.
G-Fire control.
MS-Minesweeping.
P-Electric Propulsion.
R-Radio and radar.
RL-Running, anchor, and signal lights.
S-Sonar.
XFE-Emergency lighting and emergency power.

Other letters and numbers were used in connection with these basic letters to form the complete designation. Typical marking for a power system for successive cables from a switchboard to a load would be as follows: feeder, FB-411; main, 1-FB-411; submain 1-FB-411-A; bronch, 1-FB-411-A1 and subbranch, 1-FB-411-A1A. The feeder number is indicative of the system voltage, that is, the feeder numbers for a 115-volt lighting system would range from 100 to 199 and for a 450-volt power system from 400 to 499. Electrical wiring plans on a vessel give the exact designation for each cable.

(3) The letters now being used to identify cables for the different services are as follows:

Service	*Designation*
Degaussing	D
Electronics	R
Fire control	G
Interior communications	C
Lighting, emergency	EL
Lighting, navigational	N
Lighting, ship service	L
Minesweeping	MS
Night flight lights	FL
Power, ship service	P
Power, casualty	CP
Power, control	K
Power, special frequency	SF
Power, emergency	EP
Power, propulsion	PP

Other letters and symbols are used with these basic letters to form the complete cable designation which gives the cables source, service, and designation. Typical markings for power systems cables from a generator to a load, and the meanings of the symbols, would be as follows:

Generator cables 6SG-4P-6S

6SG-Fed from ship service generator No. 6.
4P-450-volt power cable.
6S-Supplying ship service switch-gear group No. 6.

Bus feeder 6S-4P-31

6S-Fed from ship service switch-gear group No. 6.
4P-450-volt power cable.
31-Supplying load center switchboard No. 31.

Feeder 31-4P-(3-125-2)

31-Fed from load center switchboard No. 31,
4P-450-volt power cable.
(3-125-2)-Supplying power distribution panel located on third deck, frame 125, port side.

Main (3-125-2)-4P-C

(3-125-2) Fed from power distribution panel located on third deck, frame 125, port side.
4P-450-volt power cable.
C-Indicates that this is the third cable from the panel.

Submain 3-125-2)-1P-C1

(3-125-2)-Indicates circuit emanates from power distribution panel No. 3-125-2.
1P-120-volt power cable.
C1-Indicates first cable fed (through a transformer) by the main listed just above.

Branch (3-125-2)-1P-C1B

(3-125-2-Indicates circuit emanates from power distribution panel No. 3-125-2.
1P-120-volt power cable.
C1B-Indicates second cable fed by the submain listed just above.

Subbranch (3-125-2)-1P-C1B2

(3-125-2)-Indicates circuit emanates from power distribution panel No. 3-125-2.
1P-120-volt power cable.
C1B2-Indicates second cable fed by the branch listed just above.

(4) For interior communications and fire control circuits see chapter 65 of the Bureau of Ships Technical Manual.

(5) The cables are tagged as close as practicable to each point of connection, on both sides of decks, bulkheads, and other barriers. Cables located wholly within the same compartment in such a manner that they can be readily traced, need not be tagged.

(6) Cables which are not tagged in accordance with the above should be provided with the missing cable tags, embossed with the appropriate cable designation. Ships not equipped to provide and emboss their own cable tags may obtain them from a tender, repair ships, or a repair activity.

(7) The cable marking tags should be maintained intact at all times. The tags should be securely fastened to the cables and so positioned on the cable that they are readily visible.

60-271 PERIODIC TESTS AND INSPECTIONS

Conduct tests and inspections as frequently as indicated in Article 60-261 (2) by the methods outlined in Articles 60-91 to 60-111.

Chapter 61

Electric Generators and Voltage
Regulators

List of Effective Pages

PAGE NUMBERS	CHANGE IN EFFECT
1–12	Original
13–13A	Change 2
14–24	Original

Original: 1 November 1965
Change 1: Superseded
Change 2: 15 April 1967

NAVAL SHIPS TECHNICAL MANUAL
formerly
Bureau of Ships Technical Manual

NAVSHIPS 0901-961-0002

average voltage by more than one-half volt for a 120-volt generator nor by more than one volt for a 240-volt generator.

4. *Stability of operation.* Parallel operation without an equalizer will be stable when the generating units have the drooping voltage characteristic required by the condition stated in article 61–140 (1)(b), and the stability will be greater the more the voltage drops with increased load current. Excessive voltage drop is undesirable from the standpoint of system operation, but enough must be tolerated to insure stable operation. The way in which a drooping characteristic provides stability can be seen by considering a constant total load current which is supplied by two or more such generating units operating in parallel. If, for any reason, one unit should momentarily supply more than its normal share of the total current, its voltage will drop. The other unit or units, being relieved of load because the total load remains the same, will rise in voltage. These voltage changes restore the original division of load since the low voltage unit will drop its excess load, and the higher voltage units will pick it up. This is stable operation because when the system is momentarily disturbed it automatically comes back to the original condition. Shunt and stabilized shunt generators operate in this way without requiring an equalizer because they have a drooping voltage characteristic. The terminal voltage decreases when the load current increases because the inherent characteristics of the generator cause such a change even if the speed of the generator is kept constant for all loads, and, in addition, the speed of the prime mover decreases when the load is increased except when the prime mover of the generating unit is equipped with an isochronous governor which maintains constant speed irrespective of load. The decreased speed causes an additional decrease in voltage. The drop in voltage with increased load when the speed is kept constant is a characteristic of the generator alone. The drop in voltage due to the combined effect of the generator characteristic and the drop in speed of the prime mover is a characteristic of the complete unit including generator, prime mover, and governor. The overall or combined unit voltage regulation characteristic is the one which is important for parallel operation of generating units. It can be conveniently shown by a curve in which the quantity plotted horizontally is the load current expressed as a percentage of full-load current, while the quantity plotted vertically is the terminal voltage produced by the unit at each load current when the unit is running under the control of the governor so that speed decreases with increased load in accordance with the governor characteristics and setting. Examples of such curves are shown in figures 61-1, 61-2, and 61-3 for three different pairs of generators.

5. *Division of load.*

a. If, as in figure 61-1, the overall voltage regulation characteristics of two generating units are identical (or substantially identical), the two units will parallel satisfactorily and divide the total load between them in proportion to their ratings, whatever the total load may be.

b. If, however, the characteristic curves are as shown in figure 61-2, the two units will not divide the total so that each carries the same percentage of its full-load current even assuming that it has been possible to parallel the units without tripping the breakers or damaging the machines. When two units are operating in parallel, their terminal voltages must be the same except for the negligible drop in potential in the connecting leads. Reference to figure 61-2 shows that when the common terminal voltage is V volts, for example, unit No. 1 will be loaded

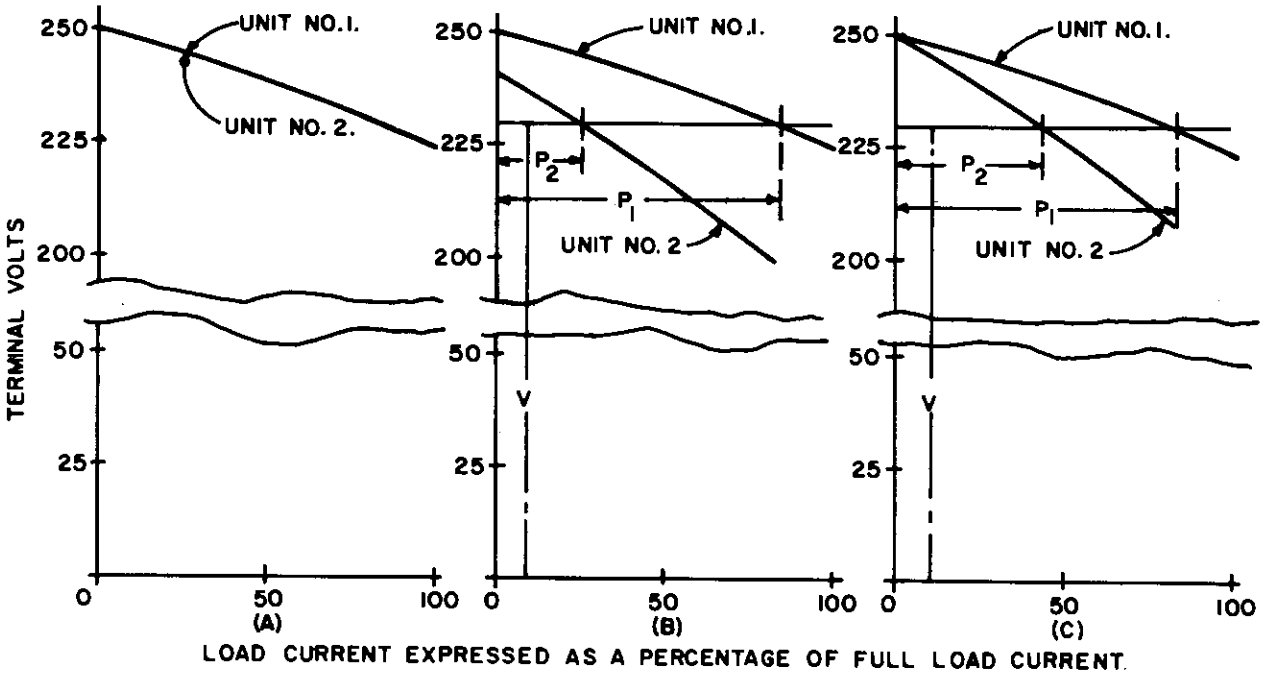


FIGURE 61-1. FIGURE 61-2. FIGURE 61-3.

to P_1 percent of full load, and unit No. 2 to P_2 percent. Unit 2 is more lightly loaded. Further consideration of the figure will show that when the total load is increased until unit No. 1 is carrying full load, unit No. 2 will still be only partially loaded. The total output that can be obtained from the two units without overloading either one is, therefore, less than the sum of their ratings.

c. By adjusting the shunt field rheostat of one or both of the units, their terminal voltages can be made to coincide at no load as shown in figure 61-3. The total load still will not divide correctly since unit No. 2 will take less than its fair share. It is necessary to change the slope of the characteristic curve for one of the units, unit No. 2, for example. This can be done by adjusting the series field diverter, or the brush position, or the speed regulation of the prime mover, or all three. By means of these adjustments, which are made once and for all when adjusting the units for parallel operation, combined with the use of the shunt field rheostats which require setting each time the units are paralleled, the terminal voltages can be made to coincide at no load and at full load. Since the characteristic curves showing terminal voltage plotted against current region are nearly straight lines in this region, the two units will properly divide the total load at all loads. Voltage is the same for each unit, the percentage of full-load current supplied by each is also the same.

61-141. ADJUSTMENT OF SHUNT AND STABILIZED SHUNT D.C. GENERATORS FOR PARALLEL OPERATION

In case the parallel operation of shunt or stabilized shunt d. c. machines is unsatisfactory, the correct solution of the difficulty is not the addition of an equalizer connection. Shunt and stabilized shunt wound generators are used on naval vessels for several reasons. One is to save the weight and space required for the installation of equalizer connections and switches. Another is to insure against the unsatisfactory operation that will be caused on an equalized system by a change in the resistance of switch contacts and connections. Since the equalizer connection must be of very low resistance, even a small change in resistance will disturb the operation. To install equalizer connections to obtain satisfactory parallel operation of shunt or stabilized shunt wound generators is to defeat the purpose of using this type of generator. The correct solution of unsatisfactory parallel operation is to adjust the units until they satisfy the conditions of article 61-140. The recommended procedure for making this adjustment is as follows:

(1) Start the prime mover of one of the generating units in accordance with the applicable instructions and safety precautions, and bring up to rated speed.

(2) Measure the voltage fluctuation at no load. If the voltage fluctuation is greater than the figure given in article 61-140 (3), do not disturb the governor adjustment