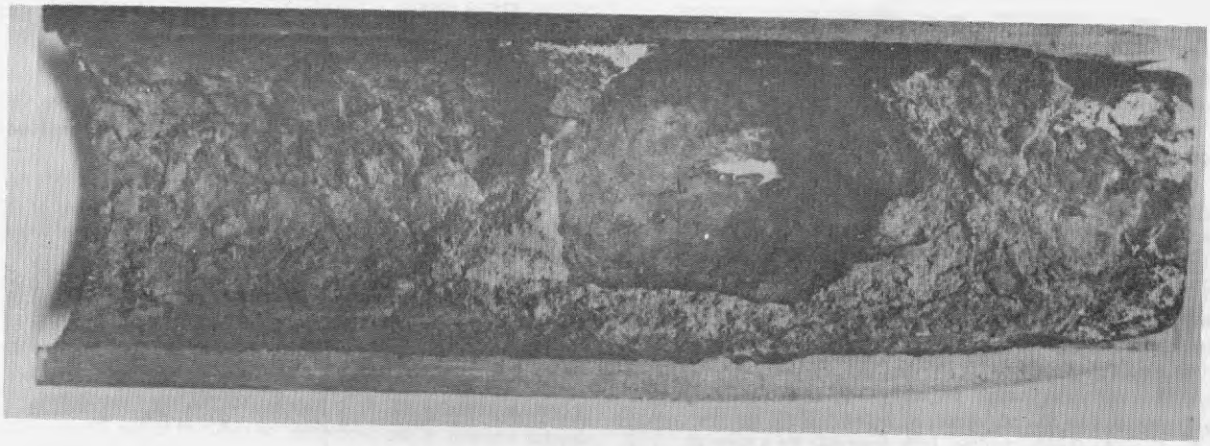


Figure 9560-3. Typical sludge in a 2-inch boiler tube.

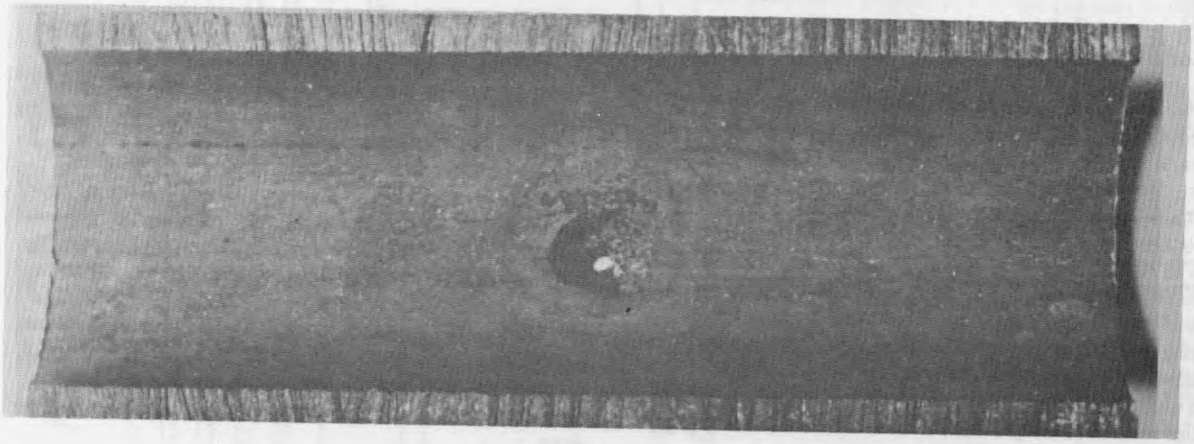


Figure 9560-4. Oxygen Pit.

Figure 9560-5. Oxygen Scab.

occur. Baked sludge is difficult to remove by mechanical means and is not disintegrated by treatment chemicals. Excessive accumulation of sludge indicates that blowdown has been inadequate. The presence of sea water resulting from excessive condenser tube leakage is a common cause of heavy sludging. The products of corrosion of condensers and feed piping systems also contribute to excessive boiler sludging.

9560.27. PROCESS OF CORROSION

1. **Corrosion Deposits and High Temperature Oxide.** Corrosion deposits, like scales, form directly in place, but they are formed by reaction of the metal with the water, as in rusting. High temperature oxide, sometimes called mill scale because it resembles the surface of newly rolled steel, is a special type of corrosion product which results from reaction of hot metal with water or air.
2. **Electrolytic Corrosion (Pitting).** All corrosion is electrolytic in nature; however, the term is usually applied to local effects like the pit shown in figure 9560-4 and the scab shown in figure 9560-5. It is possible for a tube to be completely sound except for one or two such pits. For a number of reasons, anodic and cathodic areas exist even in the most perfectly formed metal tubes. When exposed to a conducting medium (electrolyte) such as boiler water, iron goes into solution.
3. **General Corrosion.** Under certain conditions, the water in contact with the tube metal is corrosive enough so that there is general metal loss over the entire tube area. However, this phenomena rarely occurs in Naval boilers.
4. **Corrosion of Boiler Watersides.** Corrosion of boiler watersides is a special case of electrolytic corrosion. Iron in contact with water tends to go into solution, as has been previously mentioned. This effect cannot be prevented completely, but it can be reduced to a tolerable minimum. This can be accomplished by simultaneously keeping boiler-water conditions in the prescribed range and eliminating dissolved oxygen from the feedwater and boiler water. The importance of these factors is elaborated below.

9560.28. EFFECT OF LOW ALKALINITY

Acid corrosion, that is caused by low alkalinity will cause general wastage of the waterside surfaces and may be accompanied by localized pitting.

9560.29. EFFECT OF EXCESSIVE ALKALINITY

If the boiler water alkalinity is too high, strong caustic concentrations may develop in the film in contact with the evaporative surfaces. Such strong caustic solutions will then penetrate cracks in the protective film and react with the tube metal.

This process can cause severe furrowing and grooving in fire-row and studwall tubes where high evaporation rates establish a local, high concentration alkaline film. Thus it can be seen that the proper treatment is a choice of a mean between two extremes.

9560.30. EFFECT OF DISSOLVED OXYGEN

Dissolved oxygen causes localized electrolytic corrosion. Oxygen corrosion can be identified by the occurrence of scattered, localized pits and the absence of general corrosion in the intervening areas. Oxygen pitting is accelerated by increase in temperature, dissolved oxygen, and acidity (decrease in alkalinity). The normal introduction of feedwater to the top drum of a steaming boiler usually reduces the dissolved oxygen to a tolerable residual, since the evolved steam scrubs the dissolved gases away, but there is considerable evidence that traces of oxygen can cause serious pitting of fire-row of stud-wall tubes or in other relatively hot portions of the boilers. Economizers, which operate at low temperatures and can provide no escape for the dissolved oxygen, are particularly vulnerable to dissolved-oxygen corrosion.

9560.31. SOURCES OF DISSOLVED OXYGEN

Aerated feedwater is one of the principal sources of oxygen contamination of boiler water. Atmospheric oxygen is also drawn into a boiler which is secured at steaming level and permitted to cool. Air will dissolve readily in feedwater and, if not removed by the condensers or deaerating feed tanks, will pass on to the economizer and generating-tube nest. It is imperative that the dissolved-oxygen content of the feedwater be reduced to the lowest possible level before it leaves the deaerating feed tank, and that the feedwater be protected against air from leaking in during its travel through the suction lines. It is also imperative to secure a boiler to prevent oxygen from entering the boiler while it is cooling and while it is cold. Securing procedures should be as outlined in chapter 9510.17.

9560.32. PROCESS OF DEAERATION

Modern methods of deaeration take advantage of the solubility characteristics of gases. The solubility of oxygen increases with an increase in the pressure of the oxygen-bearing atmosphere above the water, and decreases with an increase in the temperature of the water. The solubility of oxygen in water at various temperatures and pressures is illustrated in figure 9560-6. This figure illustrates that at reduced pressures, the solubility of oxygen decreases rapidly with an increase in temperature and reaches zero at the temperature corresponding to the boiling point.

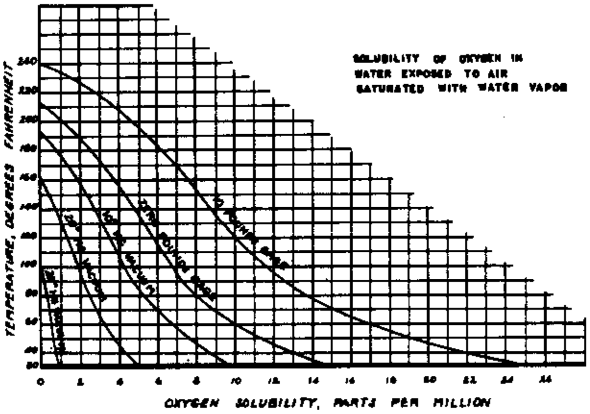


Figure 9560-6.

DEAERATION SYSTEMS

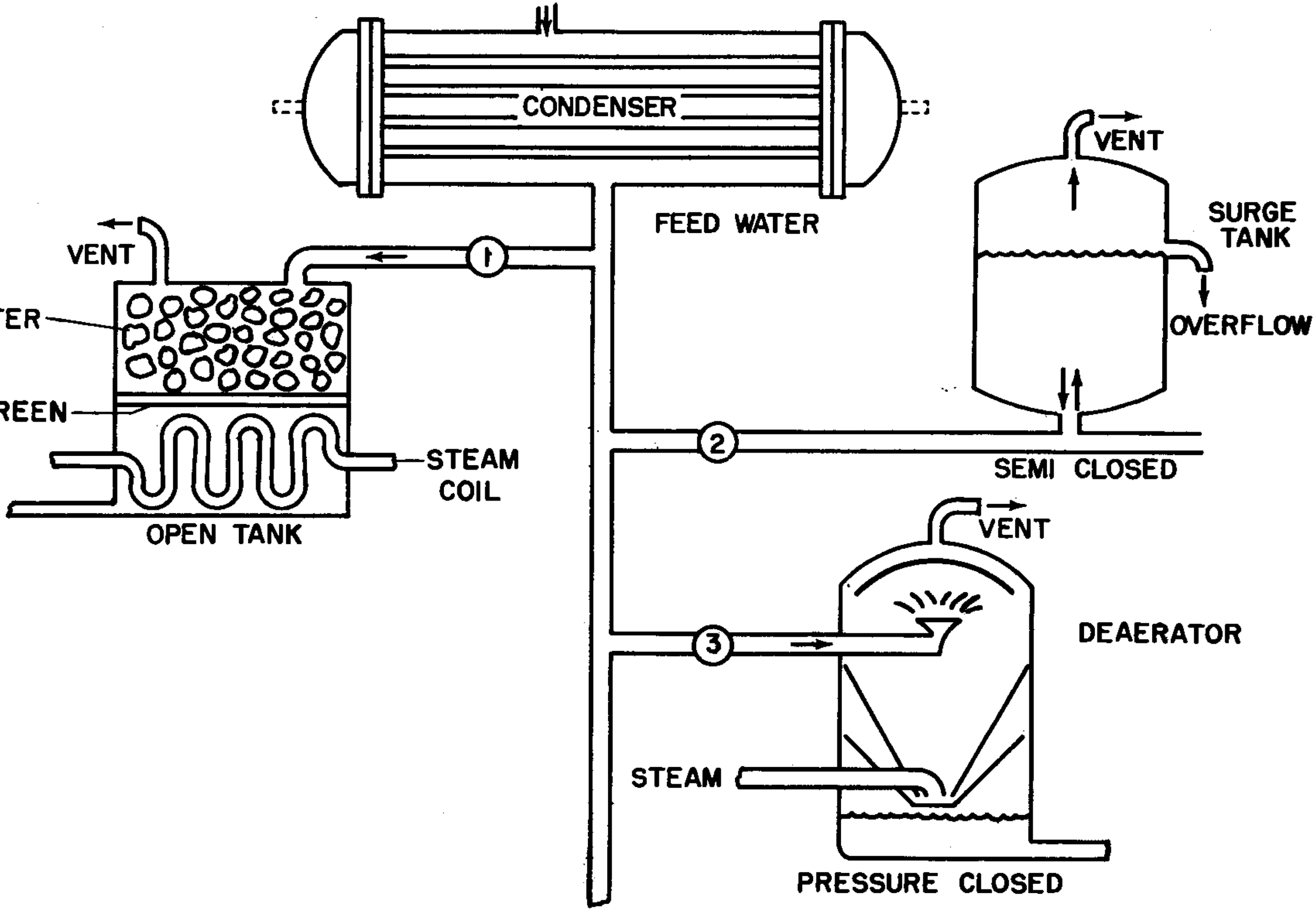


Figure 9560-7

The deaeration process simply removes gases from the feedwater by either heating to reduce solubility, applying vacuum to reduce solubility and remove gases, or scrubbing with steam to remove the gases mechanically. The three basic mechanical deaeration systems (feedwater heater systems) are the open feedwater heater, the semiclosed feedwater heater, and the pressure-closed deaerator. These systems are diagrammed in figure 9560-7. All deaeration systems must be operated carefully and checked regularly if dissolved oxygen in the feedwater is to be minimized. The deaerating principles of the several systems are discussed below.

1. **In the open feedwater system,** vacuum is obtained in the condenser with a steam-powered air ejector (aspirator principle). The low pressure reduces the solubility of the gases which pass out of the ejector. From the condenser, the water flows to an open tank where it is kept hot to minimize solution of gases. The air-ejecting, low-pressure condenser is common to all of the three systems.

The efficiency of the open feedwater system depends on maintenance of the condenser vacuum by air ejection and the extent of open feed tank heating. Low feed tank temperature is the principal source of trouble.

2. **The semiclosed feedwater system** introduces less air than the open system because it has centrifugal pumps instead of reciprocating wet air pumps, and because it uses a surge tank floating on the line instead of an open feedwater tank through which all of the water flows. The surge tank has a constant overflow near the expected water level to remove the surface layer continuously and thereby to minimize the introduction of aerated surface water to the feedwater line. The purpose of the surge tank is defeated if water is not overflowed from this point continuously by adding makeup feedwater to level out feedwater demands. Low surge tanks temperature has the same effect as low open tank temperature.

3. **In the pressure-closed deaerating system,** a spray type deaerator is substituted for the feed or surge tank. Hot feedwater from the condenser is sprayed into the deaerator shell through a number of spring loaded atomizing valves. Simultaneously, exhaust steam is blown through the spray to sweep the gases out of the vent.

The primary step in deaeration, therefore, is to raise the temperature of the feedwater to the boiling point corresponding to the deaerating feed tank pressure. This renders the oxygen insoluble, but the problem of purging the water of the last traces of oxygen and transporting the air-free water to the boiler without reaeration remains. The feedwater systems used for solving these problems are discussed in detail in section II.

9560.33. NATURE OF CARRYOVER

In addition to the prevention of scale and corrosion, the third principal object of boiler-water treatment is the prevention of such abnormal boiling conditions as priming or foaming. The greater the amount of dissolved solids in a water, the greater will be the tendency of the water to foam or froth when it is boiled violently. Solids will accumulate in the surface layer and will stabilize bubble formation so that the bubbles pile up instead of bursting. If these stabilizing forces are great enough, no amount of steam space above the liquid surface will prevent foam from carrying over into the steam line. The boiling over of a coffeepot is an everyday example of this phenomenon.

If the amount of suspended matter is considerable, any foam which forms is stabilized by the small particles and the film thickness, so that the steam bubbles fail to break before entering the dry pipe. Small particles of water then will be carried along with the steam; this process is called carryover. Excessive alkalinity will also cause the boiler water to foam and to carryover. Carryover causes wet steam and objectionable deposits in the steam lines, superheaters, and turbines. Figure 9560-8 illustrates the effects of carryover in a superheater line.

Priming is a violent type of carryover caused by erratic firing, carrying boiler water level too high, very rapid increases in steam withdrawal, and rough weather, so that large quantities of water may be thrown into the steam space as though small intermittent explosions were occurring. Large amounts of water then will be carried into the dry pipe.

Foaming can generally be controlled by reducing the amount of dissolved and suspended solids in the boiler water; however, priming is a mechanical matter.

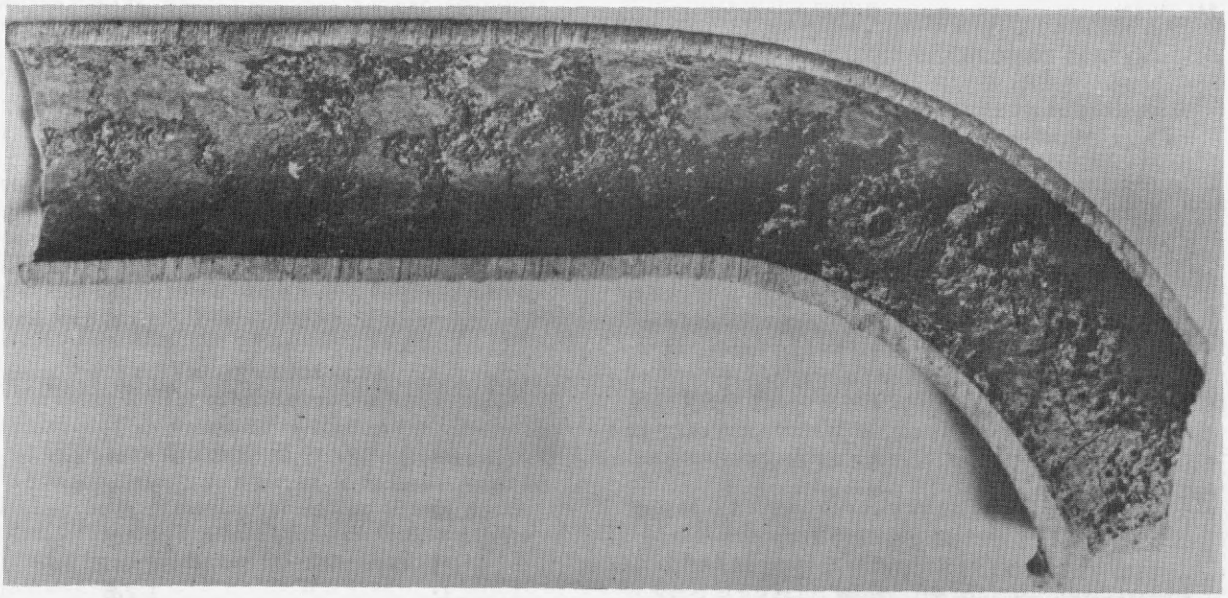
Part 4. Care of Feedwater and Makeup Feedwater

9560.41 SEA WATER DISTILLATE

All water used for boiler-feed purposes contains some undesirable impurities. It is impossible to make evaporator distillate free from all impurities. The distillate from shipboard evaporators will normally contain less than 0.065 epm of chloride. Associated with these chlorides are smaller amounts of all the other salts found in seawater. All of these impurities enter the boiler with the makeup feedwater.

9560.42 ELECTRICAL SALINITY INDICATORS

Electrical conductivity meters, or salinity indicators, are installed in virtually all naval vessels. Their operation is based upon the fact that the electrical resistance of a water solution varies with the amount of ionized salts dissolved in it. This resistance and the corresponding meter indication vary both with the temperature and the ionized salt concentration of the water flowing through the cell. Temperature compensation is provided to eliminate the temperature effects. The compensator must be set at a value corresponding to the temperature of the solution being measured. This compensation is accomplished manually in the older types of indicators and automatically in the newer types of indicators. Power factor type meters are used to eliminate the effects of line voltage fluctuations. Salinity indicators are most sensitive at low ionized salt concentrations. The salinity indicators should be operated and checked as recommended in chapter 9650 and in the manufacturer's instruction book supplied with the equipment. To further ensure that the salinity equipment is operating properly, the maintenance schedule set forth in the maintenance requirement cards (MRC) must be followed. The results obtained with the indicator may be compared with the corresponding chloride titrations (methods for determining the concentration of a substance in solution). The dials of salinity indicators are calibrated in grains of sea salt per gallon and epm of chloride. To convert the dial reading for checking against results obtained from chloride titration multiply by the factor 0.261; e.g., grains of sea salt per



Superheater Steamside Deposit.

Figure 9560-8.

TABLE II

Grains of sea salt per gallon:	Equivalents per million chloride:	Grains of sea salt per gallon:	Equivalents per million chloride:
0.1	0.026	1.3	0.339
.2	.052	1.4	.365
.25	.065	1.5	.392
.3	.078	1.6	.418
.4	.104	1.7	.444
.5	.130	1.8	.470
.6	.157	1.9	.496
.7	.183	2.0	.522
.8	.209	3.0	.783
.9	.235	4.0	1.044
1.0	.261	5.0	1.305
1.1	.287	10.0	2.610
1.2	.313		

TABLE III

Equivalents per million chloride:	Grains of sea salt per gallon:	Equivalents per million chloride:	Grains of sea salt per gallon:
0.01	0.038	0.29	1.111
.02	.77	.30	1.149
.03	.115	.31	1.187
.04	.153	.32	1.226
.05	.192	.33	1.264
.06	.230	.34	1.302
.07	.268	.35	1.340
.08	.306	.36	1.379
.09	.345	.37	1.417
.10	.383	.38	1.455
.11	.421	.39	1.494
.12	.460	.40	1.532
.13	.498	.41	1.570
.14	.536	.42	1.609
.15	.574	.43	1.647
.16	.613	.44	1.685
.17	.651	.45	1.724
.18	.689	.46	1.762
.19	.728	.47	1.800
.20	.766	.48	1.838
.21	.804	.49	1.877
.22	.843	.50	1.915
.23	.881	.60	2.298
.24	.919	.70	2.681
.25	.958	.80	3.064
.26	.996	.90	3.447
.27	1.034	1.00	3.830
.28	1.072	1.5	5.745
		2.0	7.660
		2.5	9.575

gallon (meter reading) X 0.261 = epm. chloride. For example, titration of a sample which the indicator shows to have 0.60 grain of sea salt per gallon should give a result of approximately 0.15 epm. of chloride. Tables II and III will assist the operator in making necessary conversion for checking the values read from the salinity indicator against the values in the chloride test and vice versa.

9560.43. UNDESIRABILITY OF SHORE WATER

All shore waters contain varying amounts of contaminating salts, depending on the character of the rocks, sand, and earth over which they have flowed and on the extent and nature of municipal treatment to which they have been subjected. The impurity content of shore water will always be higher and, more important, will be chemically and proportionately different from that of the sea water distillate which naval water-treatment is designed to control. Water received from shore should not be used in the boilers (except in emergency) without first being evaporated in the ship's distilling plant. Consult chapter 9580 for discussion of conditions under which the ship's distilling plant may be used for evaporating shore water and operating precautions to be taken under these circumstances. If necessary to use shore water without distillation, the water should be tested and only a neutral water, low in hardness, should be accepted for temporary use during the emergency. A neutral water is one which is colorless with phenolphthalein indicator and green with methyl-purple indicator. The evaporation of shore water, to obtain satisfactory feedwater for the boilers, may result in depositing on the evaporator tubes an extremely hard scale different from that resulting from evaporation of sea water. For the use of shore source distillate, refer to article 9560.92.

9560.44 PROTECTION OF FEEDWATER

Feedwater shall be maintained as free from impurities as possible. This requirement involves careful attention to the entire plant through which the water passes, either in the form of steam or as water, for, even though evaporator distillate quality is excellent at the time of entry into the system, by the time it is used as makeup feed, it may absorb impurities from the various parts of the installation.

9560.45 SOURCES OF SALT WATER CONTAMINATION

The most prolific source of contamination of the water in naval boilers is salt-water leakage into the feedwater system. The principal parts of the system where this leakage may occur are listed below:

1. Condensers: main, auxiliary, and dynamo.
2. Salt-water-cooled air-ejector condensers.
3. Distilling plants.
4. Salt-water-cooled gland-exhaust condensers.
5. Leaky bottom-blow valves on idle boilers.
6. Leaky feed suction and drain lines which run through bilges.
7. Leaky seams and rivets in reserve feed tanks.

9560.46 CONDENSATE CHLORIDE

Condensers are the most common source of salt-water leakage into the feedwater system. Particular attention should be given to detect leakage of salt water into the fresh-water side of condensers. In most naval installations, the condensate consistently contains less than 0.05 epm of chloride. Any consistent increase above this value is a definite indication of a leak. When a leak is detected, it should be corrected as soon as operating conditions will permit dismantling the unit affected. Attention is directed to appropriate parts of chapter 9460 for operation and maintenance of condensers.

9560.47. EFFECT OF CARRYOVER ON CONDENSATE CHLORIDE

Whenever the condensate from any condenser shows the presence of chloride to be above the usual operating value, it is well to check the steam from the boilers by testing a sample of water from one of the steam drain lines. The results of the steam-condensate analyses will indicate whether or not there is any carryover of boiler water in sufficient quantity to give more than normal chloride readings in the condensate. Sudden large increases in ship speed may cause carryover from the boilers. The effect of this carryover on the chloride in the condensate will be more pronounced the higher the chloride content of the boiler water.

9560.48. FINDING SOURCE OF CHLORIDE CONTAMINATION

It is of the greatest importance that any unusual rise in the chloride content in the feed tanks, feedwater, or boilers be investigated at once and the source of the leakage found and corrected. To locate these sources, test the feedwater from different units in the system, and where possible cut out the elements one at a time until the source of contamination is located. A test for chloride in the feedwater should be made each time one of the elements is cut out. Before making a test, the plant should be allowed to operate for several minutes without this element in commission so that the chloride concentration of the feedwater due to that element may have time to be diluted with salt-free water. The methods of testing the condensers to locate a leak are described in chapter 9460.

9560.49 LEAKING EVAPORATOR TUBES

Leaky evaporator tubes occasionally are responsible for salting up the feed system and for causing excessive sludging in the boiler water. The salting-up usually occurs after the distilling plant has been secured, when a leak in the first-effect evaporator tube nest will permit salt water to enter the first-effect tube-nest drains and eventually some part of the system. Therefore, tube-nest drains should be tested for salinity upon starting up the distilling plant. It is possible, through faulty evaporator operation, to permit the level of the brine in the shells to rise to the point where salt water backs up through the first-effect tube-nest vent line, thus contaminating the drains. The first-effect tube-nest drain line should be secured during all periods when the distilling plants are idle.

9650.50. LEAKING SUCTION LINES IN BILGES

The system may be salted up by leaky feed suction lines which run through the bilges. Such leaks will also be responsible for some loss of makeup feedwater. Periodic tests of feed-suction lines should be made, as very often leaks will exist which are responsible not only for a loss of feedwater but for loss of pumping efficiency when the lines are being used.

9650. 51. SALT WATER AND FEEDWATER CROSS-CONNECTIONS PROHIBITED

No cross-connection shall be permitted between salt water and feedwater piping.

9560.52 ELIMINATION OF AIR IN FEEDWATER

For reasons made clear in part 3, it is imperative that all possible precautions be taken to eliminate dissolved air from the boiler feedwater in order to reduce corrosion of boilers and, particularly, of economizers. Elimination consists in correcting all possible sources of air leakage into the feed system and of maintaining the efficiency of the deaerating equipment. A list of precautions is given in section II for each type of boiler feedwater system.

9560.53. ELIMINATION OF OIL AND GREASE IN FEEDWATER

The presence of oil and grease in the feedwater and in the boilers is not a frequent occurrence in naval installations. The following precautions should be effective in preventing any oil from reaching the boilers:

1. No oil shall be used for the internal lubrication of the steam cylinders or valve chests of any reciprocating machinery. Saturated steam provides enough water of condensation to give the necessary lubrication, and in superheated steam units the metals used are designed to operate satisfactorily without lubrication. The use of a pure mineral oil may be authorized by the command in in special cases only. Only a light, smooth coating of petrolatum shall be applied to the inside of cylinders at specified inspections.
2. Very little lubrication of rods is necessary and this lubrication shall be kept at a minimum by the use of small quantities of mineral oil at each application. With main reciprocating engines using forced lubrication, the oil from such parts as crossheads and quides should be prevented from splashing on the piston rods or valve stems.
3. When filters or grease extractors are fitted, they always should be used and kept in efficient condition.
4. Filtering material should be cleaned or renewed as often as found necessary as outlined in section II. Special precautions and instructions when using asbestos and diatomaceous-earth filter-aid should be observed.
5. Drains from fuel oil heaters and from heating coils in lubricating oil tanks and fuel oil tanks always shall be passed through an inspection tank before discharging into the feed system. Frequent inspections of these tanks are necessary in order that the presence of oil will be discovered soon after its first appearance, in order that drains may be diverted to the bilge until the source of contamination is removed.

9560.54 AVOIDING EXCESSIVE MAKEUP FEED

It is necessary to add makeup feedwater to the system to replace water lost by leakage. All boilers, piping, glands, and valves should be kept tight and in efficient condition. The amount of makeup feed used per hour in port and per mile under way should be checked daily and every effort made to keep these amounts at low and consistent level.

9560.55. FILLING BOILERS

A boiler which has been opened for cleaning, overhaul, and inspection should be filled with hot deaerated feedwater, treated immediately and subsequently lighted off within 48 hours after filling whenever conditions permit (see chapter 9510). The short time of a steam test is sufficient to initiate the changes in the treatment chemicals discussed in the following article, as well as mixing the boiler water thoroughly so that the maximum protection against corrosion will be insured. The hottest deaerated water available should be used for filling a boiler, the method for obtaining such water depending upon the feed system as discussed in section II. An idle boiler should always be secured in accordance with chapter 9510.17, unless it is to be lighted off immediately. Partial filling or securing boilers at steaming level introduces the possibility of steam drum general corrosion discussed in chapter 9560.31. Steam testing a boiler soon after its overhaul is good engineering practice.

Part 5 - Water Treatment-600 psi Boilers and Below

9560.71. NATURE OF BOILER COMPOUND

The system of water treatment used for naval vessels with auxiliary and propulsion boilers operating at pressures at or below 600 p.s.i. is based on the use of Navy boiler compound. This fotmula has been designed to meet the most severe conditions which are likely to be encountered in a well-managed ship. However, the factor of safety thus provided in the compound is not sufficient to warrant any laxity on the part of ship's personnel in keeping the purity of the boiler feedwater at the highest attainable point. The ingredients of Navy boiler compound are disodium phosphate, Na_2HPO4, sodium carbonate (soda ash), Na_2CO_3, and cornstarch. The first two chemicals work together in converting scale-forming salts into relatively harmless sludges. The two in conjunction are not only more thorough than either by itself but, in addition, form a mixed sludge, which, being made up of both phosphate and carbonate, has less tendency than either alone to agglomerate and form an adherent, cohesive mass. The sodium carbonate serves the additional purpose of providing the necessary alkalinity control. Actually, under boiler steaming conditions, most of the soda ash is converted to sodium hydroxide, while the remainder goes into the conditioning reaction described above. The cornstarch lends fluidity to the sludge resulting from the reaction of the other two ingredients so that it does not pack in the mud drums, but may be sluiced out easily. The cornstarch also effects a very desirable reduction in the tendency of boiler water to foam and thereby reduces carryover and moisture in the steam.

9560.72. DETERMINATION OF DOSAGE

The amount of Navy boiler compound required by a boiler may be determined from the nomographs of figures 9560-9 and 9560-10 if the volume of water in the boiler at steaming level and the alkalinity and hardness of the boiler water are known. Illustrative lines are given in figure 9560-9 to demonstrate the use of the charts. The upper line illustrates the calculation of the dosage necessary to bring the alkalinity to 3.5 epm when filling a boiler which holds 3,400 gallons at steaming level. Reserve feedwater or condensate may be assumed to have zero alkalinity so that a straight edge is held from the point of zero alkalinity on the right scale to the point of 3,400 gallons on the left scale. This line cuts the middle scale at 15 pounds, indicating that 15 pounds of Navy boiler compound are required for the initial dose. The lower line illustrates the calculation of the dosage for a steaming boiler which holds 1,500 gallons at steaming level, the boiler water of which has been found to have an alkalinity of 1.5 epm. A line from 1.5 on the right scale to 1,500 on the left scale cuts the middle scale at 3.5. This indicates that a dose of 3.5 pounds of Navy boiler compound is required to bring the alkalinity to 3.5 epm. In case hardness occurs in boiler water, the required amount of Navy boiler compound for the elimination of the hardness is calculated from figure 9560-10 in a similar manner. A straight edge is laid across the chart from the point of the determined hardness on the right scale to the point on the left scale corresponding to the water content of

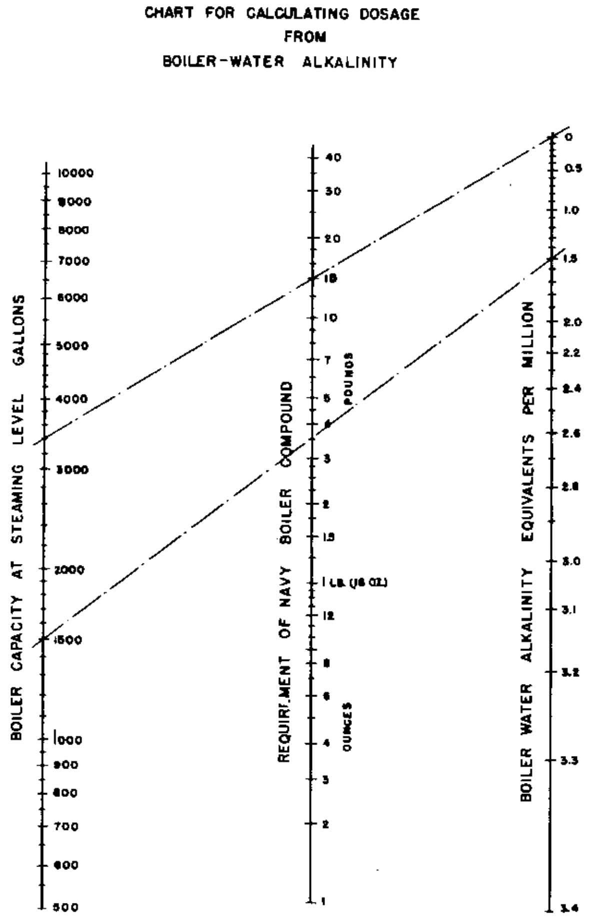


Figure 9560-9.

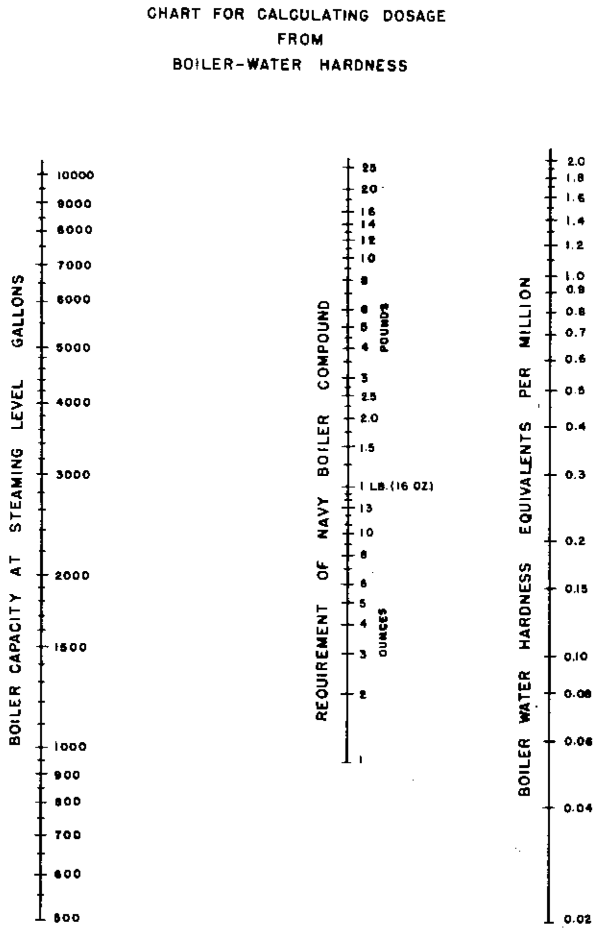


Figure 9560-10.

the boiler at steaming level. The point at which this line intersects the middle scale indicates the amount of compound required to reduce the hardness to zero. Generally when hardness is found in the boiler water, the alkalinity is low. For example, assume a boiler holds 1500 gallons at steaming level and the water has an alkalinity of 2.4 epm and a hardness of 0.04 epm. The alkalinity dosage chart should be employed in determining the necessary addition of Navy boiler compound. For this example, the two pounds of dosage required would result in a boiler water alkalinity of 3.5 epm and eliminate the hardness. The addition of one ounce of dosage would eliminate the hardness but would have little, if any, effect on the alkalinity.

9560.73 USE OF CHARTS

The amount of boiler compound calculated from figure 9560-9 as outlined above, in each case will be sufficient to raise the boiler-water alkalinity to 3.5 epm. If the boiler-water alkalinity is within the range of 2.5 to 3.5 epm, no dose need be given. However, prior to securing a boiler for bottom blowdown, the required dosage should be added to bring the boiler water alkalinity to 3.5 epm. In rare cases in which hardness occurs in boiler water, the full dose indicated by figure 9560-10 shall be added, even though this amount of compound increases the boiler water alkalinity above the higher allowable limit. The excess alkalinity then must be removed by blowdown.

9560.74. BOILER-WATER HARDNESS

The occurrence of boiler-water hardness usually is evidence that the makeup feedwater contains excessive hardness, although false soap hardness may result from the presence of zinc supplied either by condenser corrosion or from galvanized storage tanks. The amount of compound which is added to maintain the proper alkalinity should simultaneously ensure zero hardness of the boiler water if proper feedwater is used.

The source of any unusual hardness in the boiler or feedwater should be searched for, found, and corrected. If the boiler water consistently shows hardness, and the measures taken fail to remedy this condition, the Ship Systems Command shall be advised. Navy boiler compound shall be added immediately to a boiler water containing hardness.

9560.75 METHOD OF ADDING COMPOUNDS

Navy boiler compound should be mixed by stirring vigorously for about 5 minutes in hot, preferably boiling water. The mixture should be made up using about 1 pound of compound to 5 quarts of water. The compound may be added to the boilers in several ways. Each dose must be added to the individual boiler for which it is intended. The method applicable to most types of naval feed systems consists of adding the compound to the feed compound injection tank and discharging to the desired boiler through the main feed line. The feedwater should be run through the injection tank for at least several minutes to insure complete injection into the boiler and flushing of the tank. The method applicable to ships not equipped with feed compound injection tanks consists of using the emergency feed pump and discharging through the auxiliary feed line to the desired boiler, the compound being added to the feed pump suction. After the compound has been added, the emergency pump should be run a sufficient length of time to wash out the entire feedline. When only one boiler is steaming, as in port, the dose may be added directly to the port-use feed-pump or auxiliary-feed booster-pump suction. Boiler compound should be added in single or intermittent doses, but never in a continuous, dilute stream. Boiler compound should never be added to the fresh-water-drain collecting tanks.

9560.76 FREQUENCY OF TESTS OF BOILER WATER

Boiler water must be tested for alkalinity, chloride, conductivity and hardness under various conditions as follows:

1. Steaming boilers—daily and after any water treatment (Chemical addition or blowdown)
2. Idle boilers—weekly, after any treatment and prior to light off.
3. When boilers are filled with feedwater.
4. One hour after the addition of boiler compound and one-half hour after blowdown.
5. Whenever unusual conditions make it desirable.

9560.77 FREQUENCY OF FEEDWATER TESTS

1. **Alkalinity.** Alkalinity of feedwater is determined only when it constitutes the charge of a freshly filled boiler or when it consists of shore water as an emergency feed.
2. **Chloride.** Feedwater is tested for chloride in accordance with the following schedule:
   a. **Distiller discharge to reserve feed tanks** at each filling of the measuring tank.
   b. **Condensate: main condensers**—every 15 minutes while underway and every 30 minutes while standing by.
   c. **Condensate: auxiliary condensers**—every 30 minutes.
   d. **Feed tanks**—such feed tanks on the main line as deaerating feed tanks and surge tanks once each watch.
   e. **Reserve feed tanks**—Daily and prior to use.

Chloride can be determined either with the electrical salinity indicator or by the chemical method described in article 9560.106. It is recommended that the chemical method be used whenever checking feedwater from the feed tanks and reserve feed tanks. The electrical salinity indicator readings should be checked frequently by the chemical methods.

3. **Hardness.** Feedwater is tested for hardness in accordance with the following schedule:
   a. feed tanks-daily
   b. Reserve feed tanks-daily and prior to use
4. **DISSOLVED OXYGEN.** Vessels equipped with deaerators (deaerating feed tanks) shall make daily determinations of the dissolved oxygen content of the water discharged from each deaerator in operation (idle deaerators should not be tested).

Dissolved-oxygen determinations should also be made on samples of water from other points in the feedwater system to locate sources of air leaking into the system or sources of oxygen contamination of the feedwater. The prescribed methods for drawing a sample, and fixing and titrating the dissolved oxygen samples must be followed in detail if reliable results are to be obtained.

9560.78. PREPARATION OF REAGENTS

Reagents for use in the various tests on water are supplied as standard stock solutions either 10 or 20 times reagent strength, in powder form, or ready for use. These stock solutions or powders must be diluted or dissolved accurately to reagent strength with the equipment provided in the boiler-water testing cabinet. Distilled water shall be used for all dilutions of stock solution in which water is used. Standard stock solutions of reagents should be used. Requisitions should state that reagents are for use with the boiler-water testing outfit. For information regarding stock catalog numbers see article 9560.116.

9560.79. REAGENT NITRIC ACID

A twentieth normal (0.05 N) solution of nitric acid is used for alkalinity determinations. The method for the preparation of the twentieth-normal solution from standard stock solution is given below.

Preparation from stock solution. The reagent solution for use in the cabinet is made up from the stock, normal (1.0 N) nitric acid. Rinse the bottle from the cabinet marked ACID at least twice with distilled water. Rinse the 100-ml. graduated cylinder with distilled water and then a small amount of the stock acid solution. With the graduated cylinder, measure exactly 50-ml. of the stock solution of standard acid into the rinsed bottle. Fill the bottle exactly to the 1,000-ml. mark with distilled water, stopper, and shake until contents are well mixed. Remove the stopper, replace the burette assembly, and return to cabinet. Fill the burette.

9560.80. REAGENT MERCURIC NITRATE

A fortieth normal (0.025 N) solution of mercuric nitrate is used for the chloride determination. It should be prepared from the standard stock solution in accordance with the instructions given below.

Preparation from stock solution. The stock solution of mercuric nitrate is one-half normal (0.5 N) and thus is 20 times as strong as the regeant solution. Rinse the liter bottle marked MERCURIC NITRATE and the 100-ml. graduated cylinder at least twice with distilled water. Then, rinse the 100-ml. graduated cylinder with a small amount of stock solution of mercuric nitrate. Fill the cylinder to the 50-ml. mark with stock solution and transfer to the liter bottle. Fill the bottle to the mark on the neck with distilled water, stopper and shake until the contents are well mixed. Remove the stopper, replace the burette assembly, and return the bottle to the cabinet. Fill the burette.

9560.81. REAGENT SOAP SOLUTION

A hundredth normal (0.01 N) soap solution is used for determination of hardness. It should be prepared from the standard stock solution in accordance with the following instructions. The stock soap solution is 10 times as strong as the reagent solution.

1. **Preparation from stock solution** Rinse the bottle marked SOAP with distilled water and then with ethyl alcohol. Rinse the graduated cylinder from the cabinet with ethyl alcohol and then with a small amount of the stock soap solution. Fill the cylinder to the 100 ml. mark with stock soap solution and transfer to the liter bottle. Add sufficient pure ethyl alcohol to bring the level in the bottle exactly to the 1,000 ml. mark, stopper, and shake until thoroughly mixed. Replace the burette assembly and return to the cabinet. Fill the burette. Denatured alcohol should not be used for the preparation of soap solution.
2. The lather factor of a solution of soap is the amount of the solution required to form a lather which persists for at least five minutes on a sample of pure water. This lather factor is fairly constant, hence, it is assumed to be 0.4 ml.

9560.82 PHENOLPHTHALEIN INDICATOR

To prepare phenolphthalein indicator solution, dissolve 1/2 gram of phenolphthalein powder in 25 ml. of pure ethyl alcohol, add 25 ml. of distilled water, and mix well.

9560.83. METHYL PURPLE INDICATOR

Methyl purple indicator is furnished in solution ready to use.

9560.84. CHLORIDE INDICATOR

To prepare the chloride indicator solution, empty the contents of a single capsule of dry chloride indicator into the chloride indicator dropping bottle. Next add 50 ml. of 95 percent ethyl alcohol or isopropyl alcohol. Then place the stopper in the bottle and shake to dissolve the contents.

9560.85. DISSOLVED-OXYGEN TEST REAGENTS

There are two shipboard methods for dissolved oxygen in the feedwater from the deaerating feed tank. They are Method A, the titration method, and Method B, the colorimetric method.

1. Method A Reagents:

a. Reagent sodium thiosulfate - A stock solution of sodium thiosulfate 20 times reagent strength, is supplied. To make up the reagent solution for titration, remove the burette and stopper assembly from the thiosulfate reagent bottle and rinse the bottle several times with distilled water. Rinse the 100 ml. graduated cylinder from the boiler water testing cabinet with a small portion of distilled water and then with stock sodium thiosulfate solution. Measure exactly 50 ml of stock solution into the thiosulfate reagent bottle. Fill the thiosulfate bottle to the 1,000 ml mark on the neck with distilled water; stopper with the solid rubber stopper provided, and mix the solution thoroughly by shaking the bottle. Replace the burette and stopper assembly in the neck of thiosulfate bottle, return the reagent bottle to the cabinet, and fill the burette. Mark the date in pencil on the roughened area above the label of the bottle. At the end of the week, discard whatever remains of the solution and make up fresh reagent thiosulfate solution.

b. Starch indicator - Prepare starch indicator in accordance with the following instructions. Rinse and then fill the 150 ml beaker three-fourths full with distilled water. Place the beaker on the hot plate in the cabinet, heat the water to boiling, and sprinkle into it from the tip of the spatula a mound of soluble starch about one-half-inch long. Stir the boiling solution for about one-half minute with the blade of the spatula, turn off the hot plate, remove the beaker, and allow its contents to cool. Rinse the starch dropping bottle with distilled water and fill it with the cooled starch solution. Starch solution must be prepared fresh on day of test.

c. Dissolved oxygen fixing solutions - The dissolved oxygen fixing solutions (I, manganous sulfate; II, alkaline iodide; III, sulfuric acid) are supplied in the proper strength and are to be used in the reagent bottles. These reagent bottles should not be more than 1/3 filled with reagent.

2. Method B Reagents:

The three reagents for this method are supplied in plastic tubes for ready use without dilution in an amount premeasured for one determination.

a. Class A - Manganous sulfate reagent.
b. Class B - Sodium hydroxide reagent.
c. Class C - Sulfamic acid and ortho-tolidine dihydrochloride reagent.

9560.86. BOILER WATER CONDITIONS TO BE MAINTAINED

Constituent or Property	Requirements
Alkalinity, Phenolphthalein	2.5 - 3.5 epm
Hardness	Zero
Chloride	(see 9560.92)
Conductivity (For propulsion boilers only)	1300 micromhos/cm max.

9560.87. ALKALINITY AND HARDNESS LIMITS

Navy boiler compound shall be used as necessary to maintain zero hardness and alkalinity between 2.5 and 3.5 epm in the water of all boilers at all times. A ship unable to adhere to these instructions, or obtaining unsatisfactory conditions despite adherence to these instructions, shall advise the Ship Systems Command.

9560.88. ALKALINITY OF IDLE BOILERS

Until a freshly filled boiler to which boiler compound has been added has been steamed, the phenolphthalein alkalinity test does not give the total alkalinity of the boiler water. It measures only the alkalinity from the hydroxides and one-half the carbonate present. After filling an empty boiler with hot, deaerated feedwater, the alkalinity test made on the cold water with phenolphthalein indicator will show only about one-half of that expected because all the alkalinity originally introduced by the compound is carbonate.

After the boiler has been lighted-off and steamed for a few hours, the carbonate is converted almost entirely to hydroxide; thereafter the alkalinity readings will be those normally expected, even though the boiler subsequently becomes idle. If the alkalinity of a boiler freshly filled and not yet steamed is determined using phenolphthalein as the indicator, then the reading obtained must be multiplied by two to give the approximate alkalinity. This must be checked by making a test using methyl purple indicator (see article 9560.101). When the boiler contains a mixture of steamed and unsteamed water, as when a boiler is secured and then filled to its air cock, methyl purple indicator must be used since there is no way to determine the phenolphthalein correction factor.

9560.89. CONDUCTIVITY LIMITS

A direct relationship exists between the amount of ionized dissolved solids in the boiler water and the conductivity of the boiler water. Therefore, conductivity values can be used to determine when the boiler water contains an excessive amount of dissolved solids and, hence, establish when the boiler should be blown down. The maximum boiler water conductivity permitted in main propulsion boilers operating at 600 psi and below is 1300 micromhos/cm. When the conductivity exceeds this limit, the boiler must be given surface blows until the conductivity is less than 1300 micromhos/cm.

9560.90. CHLORIDE LIMITS

The chloride concentration is another indication of the amount of dissolved solids in the boiler water. To avoid the troubles caused by high concentrations of dissolved solids, the chloride concentration of the boiler water should be maintained as low as possible, preferably below 1 epm. The maximum chloride concentration permitted for boilers of various types is given below:

1. Main propulsion boilers (600 psi and lower)	2 epm max.
2. Auxiliary boilers	15 epm max.

Whenever the chloride content of a boiler water exceeds the maximum limit, the excess chloride must be removed by blowdown or the boiler secured, drained and refilled. It is better feedwater economy to secure, drain, and refill, rather than attempting to blowdown a propulsion boiler which has reached a chloride content of 5.0 epm. provided, of course, that the contaminating source has been corrected.

9560.91. FEEDWATER REQUIREMENTS

Feedwater and feedwater components normally are tested for chloride, hardness, and dissolved oxygen. Dissolved oxygen is determined only by ships having deaerating feed tanks.

The following requirements must be observed in the case of feedwater, being deviated from only in emergencies.

Feedwater Component	Requirements
Evaporator Distillate	Chloride - 0.065 epm max.
Reserve feed tanks	Chloride - 0.25 epm max. Hardness - 0.20 epm max.
Makeup feedwater	Chloride - 0.25 epm max. Hardness - 0.20 epm max.
Condensate	Chloride - 0.05 epm max.
Feedwater (Deaerating feed tanks and surge tanks)	Chloride - 0.15 epm max. Hardness - 0.20 epm max. Dissolved oxygen- 0.02 ppm max (DFT's only)

9560.92. SHORE SOURCE FEEDWATER AND STEAM REQUIREMENTS

Each shipment of shore source feedwater ("rainmaker," shore steam condensate or commercial), shall be accompanied by a certificate of analysis showing that the water meets the requirements listed below. Shore steam employed as a steam blanket on an idle boiler or as superheater protection steam during boiler light-off shall meet these requirements.

Constituent or Property	Requirements
pH	5.0 - 9.0
Dissolved Solids	10 ppm max.
Conductivity	25 micromhos/cm max.
Dissolved Silica	0.2 ppm max.
Hardness	0.1 epm max.

Each shipment of shore source feedwater shall be sampled and tested prior to acceptance for agreement with the following requirements:

Constituent or Property	Requirements
Hardness	0.1 epm max.
Alkalinity	Colorless to phenolphthalein, green to methyl purple

The hardness test shall be performed in accordance with article 9560.103. The alkalinity shall be determined as follows:

1. Measure approximately 50 ml of feedwater sample with a clean graduated cylinder.
2. Pour the 50 ml sample into a clean casserole and add 4 drops of phenolphthalein indicator.
3. Stir and observe any color development. The sample should remain colorless.
4. Rinse the casserole with distilled water.
5. Measure a second 50 ml sample of the feedwater and pour into the clean casserole.
6. Add 4 drops of methyl purple indicator, stir and observe the color of the sample.
7. The color of the sample should be green.

The collection of drains for use as feedwater, when using shore steam, is prohibited.

9560.93. ADDITIONAL FEEDWATER REQUIREMENTS

Shore water should not be used except in case of emergency. Before use, it must be distilled in the ships evaporators. Shore water should be low in hardness and chloride. In addition it should be neutral, green to methyl purple and colorless to phenolphthalein (Consult article 9560.43).

Evaporator coil drains are to be tested when starting the evaporator plant.

Figure 9560-11. Boiler water testing cabinet.

9560.94. SAMPLING BOILER WATER

The boiler water samples should be representative of the boiler water in the boiler. To accomplish this, the sample flow should pass through a sample cooler so that the sample collected is cooled to less than 100° F., preferably to 80° F. (a thermometer should be used). **The first step is to initiate coolant flow through cooler. This is an important safety step.** Sample valves before the cooler are then opened full. The sample valve after the cooler is opened until, on a steaming boiler, the sample flow flashes to steam. The cooler outlet sample valve is throttled until the sample flow is at the proper temperature. The sample container, ideally a quart plastic container with a screw cap (see article 9560.116), is rinsed three times with small portions of the sample flow. The sample container is then completely filled with boiler water sample and capped. The sample should be subjected to testing within one-half hour after collecting. The sample should be protected against contamination through undue exposure to air or particles dropping into the sample by tightly stoppering the bottle.

9560.95. SAMPLING FEEDWATER

All feedwater samples except feedwater dissolved oxygen samples shall be collected in clean plastic bottles with caps. The sampling connection or apparatus shall be flushed with the sample flow so as to aid in obtaining a representative sample. Hot samples must be cooled to less than 100° F. prior to testing (a thermometer should be used).

9560.96. COLLECTING DISSOLVED OXYGEN SAMPLES FROM DEAERATING FEED TANK

The dissolved oxygen sampling connection should be located on the side of the vertical section of the DFT outlet to the main feed booster pump upstream of any branches to other pumps in the feedwater system. The sampling lines, valves and coolers shall be installed in accordance with BUSHIPS (NAVSHIPS) Mechanical Standard Dwg. #810-1385735-B. Attach a short length of black neoprene rubber tubing, provided in the testing cabinet, to the outlet nipple of the sample line. Insert into the rubber tubing a length of glass tubing. With the cooling water secured in such a manner that shell pressure developed on the coolant side by hot sample flow is relieved, start a flow of sample water at maximum rate through the cooler or coolers to flush the sample system. Measure the approximate rate of flow. When the sample flow reaches a temperature of 140° F., as measured by a thermometer, continue the sample flow for the length of time corresponding to the flow rate in the following table:

Flow, ml. per min.	Time, minutes
600	5
500	8
400	13
300	20

Upon completion of the hot flush, start a flow of cooling water and adjust cooling water and sample flow rate for the correct conditions depending on which analytical method is employed.

Method A - Titration

The sample flow rate should be adjusted to 300 ml. per minute with a sample temperature less than 70° F. as measured by a thermometer. Insert the glass tubing to the bottom of a clean sample bottle. Allow the sample to flow continuously for seven minutes and keep the pointed glass stopper wet in water which overflows the sample bottle. Slowly withdraw the glass tubing without interrupting the sample flow and drop the glass stopper into the neck of the bottle immediately, twisting it securely in place. Hold the stopper securely in place, invert and tap the bottle gently. If a bubble is present, no matter how small, discard the sample and collect a new one. Do not confuse an imperfection in the glass with an air bubble in the sample. The sample is then treated as is given in article 9560.111.

Method B - Colorimetric

The sample flow rate should be adjusted to 500 ml. per minute having a temperature at least 70° F. but no more than 100° F. as measured with a thermometer. Insert the glass tubing to the bottom of a clean sample bottle. If the sample flow rate has been adjusted properly, the bottle should fill in two minutes. Allow the sample bottle to overflow for 12 minutes, keeping the sample bottle stopper wet in the overflow. Slowly withdraw the glass tubing without interrupting the flow. Drop the stopper immediately into the neck of the bottle. Twist the stopper with slight pressure to secure it. If a bubble is present, no matter how small, discard the sample and collect a new one. Do not confuse an imperfection in the glass with an air bubble in the sample. The sample is then immediately fixed at the sampling location as given in article 9560.111.

9560.97. EQUIPMENT FOR BOILER WATER TESTS

The equipment required for conducting all but the conductivity test is assembled in the boiler-water testing cabinet which is illustrated in figure 9560-11. A 1-liter bottle is provided for each of the following three reagents: nitric acid, mercuric nitrate, and soap solution. Each bottle has a raised or ground mark on the neck which indicates 1 liter (1,000 ml.) so that testing solutions can be made up directly in the reagent bottles without the necessity for separate measurement and mixing. A 10-ml. automatic-zero burette and an aspirator bulb for filling the burette are fitted into the stopper of each reagent bottle. In filling burettes, however, care should be taken to ensure that the delivery tip is filled to the outlet with the reagent liquid. All titrations must be started at the zero mark. The burette is designed to drain to the zero mark automatically after filling. The reading of the liquid level in a burette, pipette, or graduated cylinder should always be made at the bottom of the curved surface, called the meniscus. Do not attempt to remove the burette or bulb from the stopper. If it is necessary to replace a broken burette, the stem of the new burette and the stopper should be thoroughly wet before the new burette is inserted.

CAUTION: If the stem and stopper are not wet, the stem will bind in the stopper and may break under the force applied. Such a break produces broken glass with dangerously sharp edges that could cause serious injury to the hands.

Occasionally lubricate the stopcock of each burette with the grease provided. Excessive grease should be avoided since it will plug the burette tip and stopcock bore. Care should be exercised to avoid any pressure on the burette tip, especially when turning the stopcock. The stopcock can be manipulated best with the left hand. The thumb and forefinger should encircle the burette nozzle, with the finger ends on the stopcock handle, the right hand then is available for stirring. The following equipment also is included in the cabinet:

1. Bottle for phenolphthalein indicator.
2. Bottle for methyl-purple indicator.
3. Bottle for chloride indicator.
4. Six stirring rods.
5. Two porcelain casseroles.
6. 100 ml. and 10 ml. graduated cylinders.
7. One 8-ounce, square bottle for soap-hardness test.
8. One collapsible tube of stopcock grease.
9. Solid stoppers for reagent bottles for use in mixing testing solutions.

Replacement of any of these items may be obtained from usual naval sources. For information regarding stock catalog numbers, see article 9560.116.

The equipment used in the conductivity test consists of two elements: (1) A meter containing a compact and accurate Wheatstone Bridge with a cathode-ray tube as a balance indicator, and (2) a conductivity cell with two platinized electrodes. The meter is calibrated in terms of micromhos/cm and for accurate results must be used with a conductivity cell of definite cell constant. Information regarding stock numbers is given in article 9560.116.

9560.98. CARE OF CHEMICAL EQUIPMENT

All chemical equipment must be kept scrupulously clean if reliable results are to be obtained. All burettes should be full at all times to prevent solutions from drying on the upper walls and thus altering the strength of the reagent in the burette. The soap-solution burette can be cleaned with either distilled water or ethyl alcohol. Dishes, pipettes, and graduated cylinders should be kept clean by rinsing in distilled water and wiping immediately after each use. Rubbing with the fingers may be required to remove the purple ring left by the chloride indicator on the side of the casserole. No chemical glassware or porcelain ware should be cleaned with strong lye or scouring powders. If soap and water will not clean these properly, a weak acid solution can be used. The acid solution must be rinsed out thoroughly with distilled water.

9560.99. DETERIORATION OF CHEMICALS

Test chemicals are subject to deterioration due to storage at high temperatures and/or old age. Deteriorated chemicals are not to be used as they will lead to incorrect test results. To ensure accurate results, all test chemicals must be stored in areas where temperatures are preferably below 80° F but not exceeding 100° F. After one year, test chemicals should be discarded in accordance with BUSANDA Manual 35041.

To assist in the detection of deteriorated chemicals, standard solutions have been developed and are available in the stock system. A list of the standards and the respective stock numbers is given below:

	Standards	Federal Stock Number
Class a.-	Standard alkalinity solution, 6.0 epm methyl purple alkalinity	1H6810-985-7129
Class b.-	Standard chloride solution, 5.0 epm chloride	1H6810-985-7130
Class c.-	Standard chloride solution, 0.1 epm chloride	1H6810-985-7131
Class d.-	Standard hardness solution, zero hardness	1H6810-985-7132
Class e.-	Standard hardness solution, 1.0 epm hardness	1H6810-985-7133

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 obtained should be within the following limits:

Standard	Limits
Alkalinity (6.0 epm)	5.4 - 6.6 epm
Chloride (5.0 epm)	4.5 - 5.5 epm
Chloride (0.1 epm)	0.075 - 0.125 epm
Hardness (zero)	0.4 ml titration or less
Hardness (1.0 epm)	0.9 - 1.1 epm

If the results obtained are not within the specified limits, fresh test chemicals should be prepared 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.

9560.100. ALKALINITY OF STEAMING BOILERS

The alkalinity of water from steaming boilers, or idle boilers that have been steamed, is determined in the following manner:

1. Rinse the clean, 100-ml. graduated cylinder with some of the water to be tested.
2. Transfer exactly 50 ml. of sample into the clean porcelain casserole which has been rinsed with distilled water.
3. Add two or three drops of phenolphthalein indicator, which will give the sample a deep pink color if the sample is alkaline.
4. Fill the nitric acid burette and allow it to drain down to zero.
5. Add the reagent acid solution (0.05N) from the burette while stirring the sample continuously. Add only a drop at a time as the color begins to fade until the pink color entirely disappears.
6. Read the burette.
7. The burette reading (in milliliters) equals the alkalinity of the sample in equivalents per million. For example, a burette reading of 2.6 milliliters represents an alkalinity of 2.6 epm.

9560.101. ALKALINITY OF UNSTEAMED BOILERS

The alkalinity of water from a boiler which has not been steamed is determined by the following procedure: Measure 50 ml. of water into the procelain casserole, taking the precautions outlined above, and add two drops of methyl-purple indicator, which will give the solution a green color if the sample is alkaline. Stir the sample and simultaneously add reagent acid solution (0.05N) until the color changes to purple. A gray tint precedes the purple end point color and serves as a warning of its approach. As soon as the color of the titrated sample changes from green to purple, read the burette and record the result. This color change is quite sharp in clear water, but if the water is red with suspended iron compounds, as may be the case with boiler water, a greenish grey color frequently persists between the green and the purple rendering the end point indefinite. However, as pointed out in article 9560.94, all water samples should be free from suspended matter. If turbid water is encountered, it should be discarded for a clear sample. In the event that it is impossible to obtain a sample of clear water, an approximate value for the total alkalinity in a boiler water which has not yet been steamed can be obtained by making a phenolphthalein test and multiplying the result obtained by two. Once a boiler has been steamed, the phenolphthalein test as prescribed for steaming boilers gives the correct alkalinity. In case a boiler has been idle for more than one week, use the methyl-purple test to check the alkalinity.

9560.102. DETERMINATION OF CHLORIDE

Determine the chloride content of the boiler water as follows:

1. Rinse the clean, 100 ml graduated cylinder with some of the water to be tested.
2. Measure 25 ml of sample and pour into the clean porcelain casserole that has been rinsed with distilled water.
3. Add five drops of chloride indicator to the sample. This will turn the sample red or violet depending on the alkalinity.
4. Place the casserole under the nitric acid burette, add reagent nitric acid one drop at a time until the violet color changes to a pale yellow and then add exactly 1 ml. excess of reagent nitric acid.
5. Place the casserole under the mercuric nitrate burette and fill the burette to the zero point.
6. Add reagent mercuric nitrate solution (0.025N) from the burette while stirring continuously until the pale yellow of a sample disappears and a pale blue-violet color persists throughout the solution. The rate of mercuric nitrate should be reasonably constant during the early part of the titration then reduced to drops of the solution as the end point is approached (blue-violet color).
7. Read the burette.
8. The burette reading in milliliters equals the chloride content of the sample in equivalents per million. For example, a burette reading of 5.5 ml. indicates a chloride concentration of 5.5 epm in the sample. In case the chloride concentration exceeds 20 epm, it will be more convenient to use a correspondingly smaller sample of boiler water rather than to refill the burette repeatedly. In such a case, dilute the smaller sample to 25 ml. in the graduated cylinder with distilled water and mix well. The chloride concentration of the original sample can then be calculated as follows:

$$\frac{\text{Burette reading (ml.)} \times 25}{\text{Volume of solution diluted (ml.)}} = \text{epm of chloride}$$

For example, if a 5 ml. sample is diluted to 25 ml., and the burette reading is 10 ml., then the chloride content is calculated as follows:

$$\frac{10\text{ ml.} \times 25}{5\text{ ml.}} = 50\text{ epm}$$

9560.103. DETERMINATION OF HARDNESS

Determine the hardness content of the boiler water as follows:

1. Rinse the clean, 100 ml. graduated cylinder with some of the water to be tested.
2. Measure 50 ml. of sample and pour into the 8-ounce bottle which has been rinsed with distilled water.
3. Fill the soap burette and allow it to drain down to zero.
4. From the burette, add 0.4 ml. of soap solution; stopper the bottle, and shake it vigorously. Lay the bottle on its side on the bottom of the cabinet and start a stop watch.
5. If the lather persists and completely covers the surface of the water for 5 minutes, report "zero hardness."
6. If the lather does not persist, add more soap solution, in 0.1 ml increments; stopper and shake. Lay the bottle on its side and start a stop watch.
7. Repeat (6) until a lather is obtained which completely covers the surface of the water for 5 minutes.
8. Read the burette.
9. Subtract 0.4 from the burette reading.
10. The burette reading minus 0.4 times 0.2 equals the hardness of the sample in equivalent parts per million. For example, if the titration is 0.6, the hardness of the sample is 0.04 epm:

$$(0.6-0.4) \times 0.2 = 0.04\text{ epm}$$

The amount of soap solution to be added under paragraph six will vary between 0.1 ml and 0.5 ml. A few titrations on waters of different hardness values will aid in gaging a proper addition. Too much soap solution should never be added.

9560.104. DETERMINATION OF CONDUCTIVITY

1. Connect the conductivity meter and the conductivity cell and warm up the instrument in accordance with the manufacturer's instructions.
2. Add a sufficient quantity of sample solution to a 250 ml beaker so that the air holes of the conductivity cell are at least ½" below the surface of the water.
3. Rinse the conductivity cell with distilled water.
4. Place the cell in the boiler water sample. Move the cell up and down under the solution several times to insure removal of air bubbles inside the cell. Immerse the cell to a point above the air vents.
5. Measure the temperature of the solution with a thermometer; then set the temperature compensation dial to the corresponding value.
6. Adjust the conductivity dial until the tuning eye deflects to the widest angle.
7. Record the conductivity reading on the Boiler Record Sheet (NAVSHIPS 114).
8. When the conductivity determination is completed, rinse and store the conductivity cell in distilled water. Distillate from shipboard distilling plants is adequate for this purpose.
9. If it is necessary to store the cell out of water at any time, rinse the cell well before it drys. If this is not done, an insoluble coating may form on the electrodes which will result in lack of sharpness of the "eye". Sharpness can frequently be restored by dipping the cell for about two minutes in 10-15 percent by weight hydrochloric acid and then rinsing well with distilled water. The cells should be replaced if no improvement is noted after this treatment. Every three months, check the accuracy of the meter and cell using the standard solution described below for this purpose.

Class 1 - Standard conductivity solution, FSN 1H 6810-945-7682, 1400 micromhos/cm.

The analytical results obtained should be in the range of 1300 to 1500 micromhos/cm. If the results are not within these limits, a shipyard chemist should be contacted at the earliest opportunity for assistance in locating and correcting the source of error.

9560.105. FEEDWATER TESTS

Alkalinity is not determined on feedwater except when the feedwater constitutes the charge of a freshly filled boiler or when it consists of shore water used as emergency feed. Methyl purple indicator is used for determining alkalinity of a freshly filled boiler. This test is made only to determine the proper initial boiler-compound dosage.

9560.106. CHLORIDE DETERMINATION

To obtain the chloride content of feedwater in terms of epm, the chloride test is the same as that outlined in article 9560.102 for boiler water, except that the sample size is 100 ml. and the burette reading is divided by four. For example, if 100 ml. of feedwater requires 2.0 ml. of mercuric nitrate, the chloride concentration is (2.0 + 4) or 0.5 epm.

9560.107. HARDNESS DETERMINATION

The methods for determining and calculating soap hardness in normal feedwater are identical with those outlined for boiler water in article 9560.103. This method should be supplemented as indicated below when the hardness of shore water is being determined since such waters frequently yield false end points.

9560.108. ASSURANCE AGAINST FALSE END POINT

When determining the hardness of samples in which a false end point is suspected, follow the procedure below. Determine the hardness as described in article 9560.103 and record the amount of soap solution required for the 5-minute lather. Add 0.5 ml. more soap solution and shake the bottle vigorously. If the lather persists for 5 minutes, use the original titration value (milliliters required to form the first 5-minute lather) in calculating soap hardness. If the lather is destroyed or fails to persist 5 minutes, continue adding soap solution in 0.1 ml. increments until a stable lather is established. Calculate the true hardness from the total volume of soap consumed by the method given in article 9560.103. A second false end point will not occur.

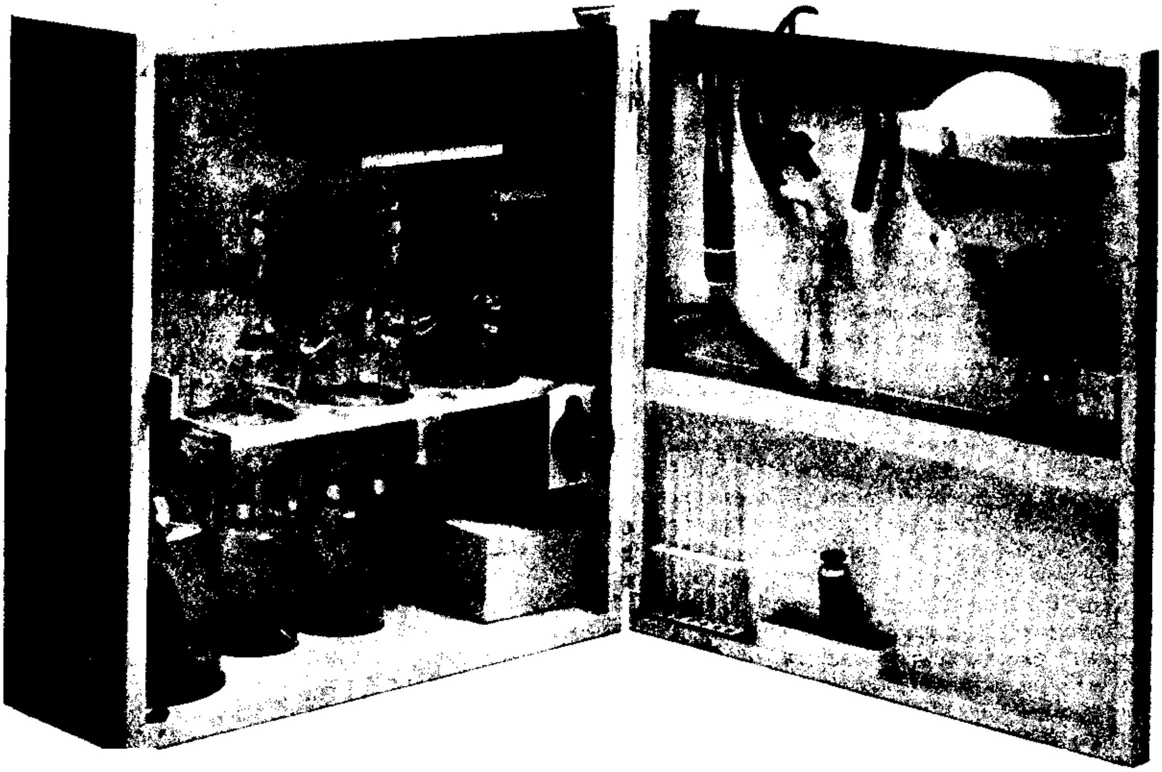


Figure 9560-12. Dissolved oxygen testing cabinet, Method A

9560.109. DISSOLVED OXYGEN TESTING EQUIPMENT

Method A - Titration

The cabinet is illustrated in figure 9560-12. The principal items in the cabinet are three 400 ml. reagent bottles, each with a side arm aspirator and a 2 ml. automatic zero pipette, for manganous sulfate, alkaline iodide, and sulfuric acid solutions; one-liter reagent bottle with an aspirator and a 10 ml. automatic zero burette for sodium thiosulfate solution; two sample bottles with conical pointed glass stoppers; a hot plate and beaker for preparing starch solution; and a large casserole for making titrations. The cabinet also contains glass and rubber sampling tubing, a bottle of saluble starch, a starch dropping bottle, a thermometer, a spatula, and a tube of lubricant.

Method B - Colorimetric

The principal items in this cabinet are the following:

1. Two one-liter sample bottles with ground glass stoppers
2. One bottle rack
3. One colorimetric comparator
4. Four comparison tubes
5. Three color standards representing 0.02, 0.04, and 0.06 parts per million (ppm) dissolved oxygen
6. A plain glass disc representing 0.00 ppm dissolved oxygen
7. One pair of scissors
8. One holder for three reagent tubes
9. One two-foot length of 3/8 inch i.d. rubber tubing
10. Six 10 in. lengths of glass tubing

For information regarding stock catalog numbers, see article 9560.116.

9560.110. CARE OF OXYGEN TESTING EQUIPMENT

General rules for the care of equipment are given in article 9560.98. Additional precautions are required for maintaining oxygen testing equipment in satisfactory working order.

Method A - Titration

The manganous sulfate (I) and alkaline iodide (II) solutions are very concentrated so that a slight evaporation clogs the discharge tubes of their pipettes. The alkaline iodide solution, in addition, will attack the glass of its pipette and cause freezing of the stopcock if it is allowed to remain in the pipette for more than 8 hours. These difficulties can be avoided if both pipettes are cleaned promptly after each use. To clean the manganous sulfate (I) pipette, fill the beaker with distilled water and raise it slowly onto the tip of the pipette with the stopcock opened, then lower the beaker and permit the stopcock tip to drain. Repeat this operation several times with at least two changes of water. Perform the same rinsing operation of the alkaline iodide (II) pipette with at least two changes of distilled water, finally removing the stopcock plug from the alkaline iodide (II) pipette and allowing it to remain covered with distilled water in the beaker until the next use of the cabinet.

CAUTION: The alkaline iodide (II) and sulfuric acid (III) solutions are very strong, corrosive reagents. Care should be taken to avoid spilling either of these solutions on the person or the clothing of the operator or in the cabinet. A further danger is that mixing these concentrated solutions causes a violent reaction which results in spattering. Accidental mixing can be avoided by clearly marking the 400 ml. reagent bottles from left to right with I (manganous sulfate), II (alkaline iodide), III (sulfuric acid). An etched circle is provided on each bottle for such pencilled markings.

Method B - Colorimetric

The sample bottles must be kept scrupulously clean at all times. The bottles should not be used for anything else but collecting dissolved oxygen feedwater samples. If the ground glass of the stopper or the neck of the bottle becomes scored, the bottle should be replaced. Dust must not be allowed to accumulate on the surfaces of the color comparator; therefore, the comparator should only be exposed when inserting vials for the actual dissolved oxygen determination. The scissors should be rinsed with water and dried immediately after use. The vials employed in the colorimetric comparison should be rinsed with water after every use. The bottoms of the vials should not be scratched or marred in any way. The class B and class C reagents are strong, corrosive reagents. Care should be taken to avoid spilling either of these reagents on the person.

9560.111. FIXING DISSOLVED OXYGEN SAMPLES

The methods for fixing dissolved oxygen samples collected as prescribed in article 9560.96 are given below:

Method A - Titration

1. Replace the plug, which has been stored in water in the beaker, in the stopcock of the oxygen II pipette, and close the stopcocks on all three pipettes. Fill each pipette using the aspirator bulb.

   CAUTION: The capacities of the pipettes are small so that care must be exercised in filling, or excess reagent will be forced out of the vent hole. Upon release of pressure, excess reagent will siphon back into the bottle. Drain a small amount from each pipette into the 150 ml. beaker so that each pipette tip is full of reagent without any air bubbles. Discard the drained reagent and rinse the beaker. Refill the three pipettes.

2. Remove the stopper from the sampling bottle and raise it onto the tip of the oxygen I pipette; open the stopcock on the pipette and allow the contents to drain into the sample.
3. As the level of the solution in the pipette drops into the tip, lower the sample bottle from the tip of the oxygen I pipette, and immediately raise the sample bottle onto the tip of the oxygen II pipette, opening that stopcock.
4. Allow the contents of oxygen II pipette to drain completely into the sample bottle, lowering the sample bottle as the liquid level drops in the pipette tip. Replace the stopper in the sample bottle and close the stopcocks on the oxygen I and oxygen II pipettes.
5. Pour to waste the excess solution around the neck of the stopper and then, holding the neck of the sample bottle between two fingers with the thumb on top of the stopper, swing the sample bottle in a horizontal circle to mix the contents thoroughly.
6. Allow the sample to stand until the precipitate settles and the sample is clear above the shoulder of the bottle.
7. Remove the stopper and raise the bottle onto the tip of the oxygen III pipette, opening the stopcock on the pipette.
8. When the contents of the pipette have drained into the sample, close the stopcock; replace the stopper; and again swirl the sample to mix it thoroughly.
9. When all the precipitate has dissolved and the sample is clear, it is fixed, and may be exposed to the air.

Method B

1. Prior to collecting sample, cut off the tops of the tubes, Class A reagent and Class B reagent, and place them in their respective holes in the reagent holder. Invert the Class C reagent tube and cut off the bottom. Place this tube in the reagent holder.
2. Carry the reagent holder containing the reagents to the sampling location.
3. Immediately upon collection of the sample, proceed quickly, after removing the stopper from the sample, to invert the Class A reagent over the bottle opening and have the tube opening about 1/2 inch above the surface of the water. Squeeze the tube thereby injecting the reagent into the sample. Quickly add the Class B reagent in the manner.
4. Immediately drop the glass stopper into the neck of the bottle. Twist the stopper to secure and mix the contents of bottle by swirling in an almost horizontal circle.
5. Let the bottle stand until the precipitate settles below the shoulder of the bottle.
6. Remove the stopper and quickly add the reagent Class C.
7. Immediately drop the stopper into the neck of the bottle. Twist to secure. Mix the contents as before.
8. If at any time, an air bubble is entrapped in the bottle up to this point, the sample should be discarded and a new one collected. Most air bubbles are introduced by too careful insertion of the stopper into the neck of the bottle. Just drop the stopper into the bottle when required to do so, giving a slight twist with gentle pressure.
9. When all the precipitate has dissolved and the sample is clear, it is fixed, and may be exposed to the air.

9560.112. DISSOLVED OXYGEN DETERMINATION

The fixed samples of article 9560.111 are determined as follows:

Method A - Colorimetric

Titration must be completed within 15 minutes after fixing and within 30 minutes after the sample has been collected. The temperature of the fixed sample must be below 70° F. during the titration with sodium thiosulfate.

1. Fill the burette in the thiosulfate bottle using the aspirator.
2. Place the iron ring in the holder between the thiosulfate bottle and the rack for sampling bottles.
3. Place the clean casserole which has been rinsed with distilled water in the ring beneath the tip of the thiosulfate burette.

4. Pour to waste any liquid from the neck around the stopper of the sampling bottle; remove the stopper; and pour the entire contents of the sampling bottle into the casserole.

5. Add about 10 drops of starch solution from the dropping bottle to the sample in the casserole. (Note in article 9560.85 that starch solution must be made up fresh daily.)

6. If no blue color appears in the sample at step 5, record the oxygen value as less than 0.02 ppm.

7. If the solution turns blue, add thiosulfate solution from the burette, drop by drop, stirring continuously with a glass rod or length of glass tubing until the blue color just disappears.

8. Read the burette and multiply the reading by 0.2. The resulting figure is the dissolved oxygen content of the sample in parts per million. For example:

Burette reading = 0.4

0.4 x 0.2 = 0.08 ppm dissolved oxygen

Method B – Titration

The determination must be completed within 10 minutes of fixing the sample.

1. Rinse a clean comparison tube with a small amount of the fixed sample. Discard the rinse. Fill the tube to mark with the fixed sample.

2. Turn on light switch to the right of the tube holder.

3. Move comparator forward and insert the comparison tube in the hole to the left of 0.02 ppm standard.

4. Compare the color of the sample to the color of 0.02 ppm standard color.

5. If the sample is less yellow than the 0.02 ppm standard, report less than 0.02 ppm.

6. If the color of the sample matches the 0.02 ppm standard, report 0.02 ppm.

7. If the color of the sample is more yellow than the 0.02 ppm standard, move the sample tube to obtain a color match or a position between two standard colors.

8. If the color of the sample matches one of the standards, report the value of the matching standard.

9. If the color of the sample is between two standard colors, report the average value.

10. If the color of the sample is more yellow than 0.06 ppm standard, transfer the sample to a graduated cylinder, add an equal amount of distilled water to the graduated cylinder, mix and pour back into the comparison tube to the mark. Proceed as above and multiply result by 2.

11. When test is completed, record result in working log, switch off light, rinse all glassware with distilled water, store the equipment and close comparator.

9560.113. INTERPRETATION OF RESULT

Deaerating feed tanks are guaranteed by their manufacturers to reduce the dissolved oxygen concentrations of feedwater to less than 0.014 ppm. A result greater than 0.02 ppm of dissolved oxygen is evidence of malfunctioning of the deaerator, the source of which should be sought and corrected. Despite the fact that normal results on a well-run ship will be 0.02 ppm or less on successive days, there should be no relaxation of the several precautions enumerated in foregoing articles and daily dissolved oxygen determination should not be omitted.

9560.114. BLOWDOWN

Blowdown is one of the most neglected treatments in shipboard service. Since it represents an apparent waste of water, personnel are prone to minimize blowdown and to permit solid concentration. This lack of blowdown is primarily responsible for failures from baked sludge. Blowdown points are shown in figure 9560-13.

Inasmuch as the conductivity test is the guide to blowdown, it only measures the amount of ionized dissolved solids in the boiler water. It does not indicate the presence of such corrosion sludges as iron oxide. Consequently, some blowdown must be given even if the conductivity is low. At the present time, it is required that the boiler be given a 10-percent surface blow daily. This daily surface blow should keep the chloride and other dissolved solids in check. If it does not, apply extra surface blows to keep the conductivity and chloride below the limit.

The procedure for calculating the amount of water employed in performing blowdown is as follows:

1. Just prior to the blowdown with the boiler steaming at normal water level, obtain a boiler water sample.

2. Determine and record the conductivity result of this first boiler water sample.

3. Perform the blowdown procedure.

4. Collect a second boiler water sample after the boiler has been steaming for 30 minutes at normal water level.

5. Determine and record the conductivity result of the second boiler water sample.

6. Calculate the percent (%) blowdown by substitution of the respective conductivities in the following:

$$\frac{\text{(Before blowdown conductivity - After blowdown conductivity)}}{\text{Before blowdown conductivity}} \text{ X } 100 = \text{\% Blowdown}$$

For example:

Assume that the conductivity before blowdown = 900 micromhos/cm

Assume that the conductivity after blowdown = 810 micromhos/cm

Then the percent blowdown is found by substituting in the formula given in step #6 above

$$\frac{900 - 810}{900} \text{ X } 100 = \frac{90 \text{ X } 100}{900} = 10\% \text{ blowdown}$$

In addition to the daily surface blows, the boilers must be given periodic bottom blows to remove solids which have settled out of the water. Blowdown should be applied before adding treating chemicals rather than after adding treating chemicals. Bottom blows also should be applied each time the boiler is secured and whenever the boiler water is turbid.

The methods for applying blowdown and the recommended uses are given in articles 9510.361-.365.

9560.115. TEST RECORDS - WATER TREATMENT LOGS FOR FEEDWATER AND FOR BOILER WATER OF 600 PSI BOILERS AND BELOW

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

2. For boiler water of 600 psi boilers and below: Boiler water treatment logs - NAVY BOILER COMPOUND (NAVSHIPS 9560/1) are provided for boiler water tests of 600 psi boilers and below.

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.

9560.116. STOCK INFORMATION FOR WATER TREATMENT CHEMICALS, TEST CHEMICALS AND EQUIPMENT

1. Navy Boiler Compound, Specification MIL-B-3242, 50 lb. drum, FSN 6850-255-0429.

2. Boiler water testing outfit Specification No. MIL-W-16642 distributed from Naval Supply Centers, Norfolk and Oakland.

6640-372-0839 - Complete outfit includes the following standard stock items (individual items may be requisitioned separately):

1 Tube, collapsible, stopcock lubricant	9150-273-2406
3 Aspirator-bulb assemblies for filling burettes	6640-291-1162
1 Dropper bottle "TK" 60 ml. for methyl-purple indicator	6640-264-8307
1 Dropper bottle "TK" 60 ml. for phenolphthalein indicator	6640-264-8308
1 Dropper bottle "TK" 60 ml. for chloride indicator	6640-264-8306
1 Bottle, 8 oz. square for hardness test	8125-179-0136
1 Reagent bottle, 1-l. for nitric acid solution	8125-253-2495
1 Reagent bottle, 1-l. for mercuric nitrate	8125-253-2498
1 Reagent bottle, 1-l. for soap solution	8125-253-2497
3 Burettes, automatic-zero, 10 ml. capacity	6640-264-6951
1 Cabinet	6640-292-3679
1 Casserole, porcelain, white	6640-271-1398
1 Cylinder, 10 ml. capacity, graduated	6640-264-8302
1 Cylinder, 100 ml. capacity, graduated	6640-264-8303
6 Rods, stirring, glass, 7 in long, 3/16 in. diameter	6640-290-0154

3. Reagents-Boiler water testing, Specification No. MIL-C-15000:

Nitric acid solution, 1.0 normal, 1-qt. bottle	6810-270-9978
Mercuric nitrate solution, 0.5 normal 1-qt. bottle	6810-281-4163
Stock soap solution, 0.7 normal, 1-qt. bottle	6810-252-1345
Methyl-purple indicator, 4-ounce bottle	6810-616-9185
Phenolphthalein (indicator), 1-oz. bottle	6810-134-0000
Chloride indicator, 12 capsules	HA6810-753-4907
Ethyl alcohol, ACS, 1-gal. can (For preparing soap, phenolphthalein and chloride indicator solutions)	6810-264-6507
Isopropyl alcohol, ACS, 1-gal. (For preparing chloride indicator)	6810-227-0410

4A. - Method A. Dissolved oxygen testing outfit Specification No. MIL-T-20641 distributed from Naval Supply Centers, Norfolk and Oakland.

6640-372-0840 - Complete outfit includes the following standard stock items (individual items may be requisitioned separately):

1 Tube, collapsible, stopcock lubricant	9150-273-2406
1 Electric heater unit, ring-type (hot plate)	6640-290-4404
4½ ft. rubber tubing	4720-189-9718
1 Aspirator-bulb-assembly for filling burettes	6640-291-1162
3 Aspirator-bulb-assemblies for filling pipettes	6640-291-8076
1 Beaker, Griffin, 150 ml.	6640-264-8313
1 Dropper bottle for starch-indicator	8125-179-0142
2 Sampling bottles, 300 ml.	8125-179-0143
3 Reagent bottles, 400 ml.	8125-285-8489
1 Reagent bottle, 1000 ml.	8125-248-9010
1 Burette, 10 ml. capacity	6640-264-6951
1 Metal cabinet	6640-292-3676
1 Casserole, porcelain, 500 ml.	6640-271-1397
3 Pipettes, 2 ml. capacity	6640-290-4407
1 Spatula, laboratory, steel, nickel-plated	6640-174-1967
6 Lengths tubing, glass	6640-245-7130

4B. - Method B. Dissolved oxygen testing outfit specification MIL-T-24209(SHIPS) distributed from Naval Supply Centers, Norfolk, Oakland, and Long Beach.

6850-985-2988 - Complete outfit

5A. - Method A. Reagents for Method A dissolved oxygen testing specification No. MIL-C-20640.

Manganese sulfate solution 1-qt. bottle, (solution I)	6810-290-3842
Alkaline potassium-iodide solution, 1-qt. bottle (solution II)	6810-290-3843
Sulfuric acid solution, 1-qt. bottle (solution III)	6810-290-3836
Sodium thiosulfate solution, 0.15 normal, 1-qt. bottle	6810-270-5553
Soluble starch, 1-oz bottle	6810-818-1813

5.B. – Method B. Reagents for Method B dissolved oxygen testing specification No. MIL-C-24208(SHIPS).

Class A – Manganous sulfate reagent, box of 12 tubes	6810-926-9136
Class B – Sodium Hydroxide reagent, box of 12 tubes	6810-926-9137
Class C – Sulfamic Acid – Orthotolidine reagent, box of 12 tubes	6810-926-9138

6. Conductivity Testing Equipment.

Solubridge, specific conductance, 50-8000 micromhos/cm	IP6625-620-4539
Dip-type conductivity cell, cell constant of 2.0	IP6630-620-4540
Beaker, plastic (Griffin style), 250 ml	9L6640-720-2755
Thermometer, metal, dial type (0-220°F)	6685-290-5533
Class i standard conductivity solution (1400 micromhos per cm)	6810-945-7682

7. Sample Bottles.

Polyethylene bottle, 1-qt., screw cap	8125-326-5479

Part 6 - Water Treatment - 1200 psi Boilers

9560.131. NATURE OF TREATMENT

It is necessary to control the quality of the boiler water in 1,200 psi boilers within narrower limits than can be maintained with Navy Boiler Compound. For such closer control, two chemicals, disodium phosphate, and caustic soda (sodium hydroxide), have been substituted for boiler compound to provide independent control of pH (instead of alkalinity) and phosphate (instead of hardness). Treatment consists simply in adding either chemical in small increments as necessary to keep the proper balance of pH and phosphate. For closer control of the dissolved solids in the boiler water, an electrical conductivity method is used to determine the need for blowdown. The method of mixing and adding chemicals, testing for chloride and blowing down are essentially the same as on other naval vessels. The tests for alkalinity and hardness are no longer required for boiler water, but hardness still is required for feedwater.

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

9560.71.	Nature of Navy Boiler Compound.
9560.87	Alkalinity and Hardness limits.
9560.72.	Determination of Dosage.
9560.73.	Use of Charts.
9560.74.	Boiler-Water Hardness.
9560.88	Alkalinity of Idle Boilers.
9560.100	Alkalinity of Steaming Boilers.
9560.101	Alkalinity of Unsteamed Boilers.
9560.103	Determination of Hardness.

9560.132. CHEMICAL TREATMENT OF BOILER WATER

1. **Determination of dosage to a freshly filled boiler.** The amounts of disodium phosphate and caustic soda needed to raise the phosphate content and pH value of the boiler water approximately to the specified upper limits are shown in table IV.

Table IV
Low Phosphate Treatment

Gallons Untreated Water Added	Ounces Disodium Phosphate To Be Added	Ounces Caustic Soda To Be Added
100	0.5	1
500	2.5	5
1000	5.0	10
1500	7.5	15
2000	10.0	20

2. **Determination of dosage to a steaming boiler.** Add disodium phosphate or caustic soda as required to maintain the phosphate content and pH value of the boiler water within the specified ranges. The amount of disodium phosphate needed to raise the phosphate content to 25 p.p.m. may be estimated by use of figure 9560-14. For example, to raise the phosphate content from 8 p.p.m. to 25 p.p.m. draw a horizontal line from 8 p.p.m. on the vertical scale. Draw a vertical line down from where it intersects the disodium phosphate line. Read the amount of phosphate to be added at the point where the vertical line intersects the horizontal scale. In this example, approximately three and one-half ounces of disodium phosphate are needed for each 1,000 gallons of water in the boiler.

To determine the amount of caustic soda needed to maintained the pH of the boiler water within limits, figure 9560-15 should be used. For example, to raise the pH of the boiler water from 10.2 to 11.0, draw a horizontal line from 10.2 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 vertical line intersects the horizontal scale. In this example, approximately six and one-quarter ounces of caustic soda are needed for each 1000 gallons of water in the boiler.

3. **Addition of chemicals to the boiler.** Completely dissolve the disodium phosphate in several gallons of hot water and feed the solution to the boiler. Completely dissolve the caustic soda in several gallons of cold water before adding to the boiler. Care shall be taken to ensure the following:

a. the chemical treatment is not lost in the bilge

b. the chemical treatment is fed to the boiler requiring the treatment

c. the treatment tank and lines are well flushed

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

9560.133. FREQUENCY OF BOILER WATER TESTING

The boiler water will be sampled and tested for pH value, phosphate content, chloride content and conductivity as listed below. Sample the boiler water from the water drum through a cooler capable of reducing the temperature to 100° F. or less. The boiler water will be retested for pH value, phosphate content, chloride content and conductivity one-half hour after blow-down and one hour after addition of chemicals.

1. Sample and test freshly filled boilers hourly until proper water conditions have been established.

BOILER BLOWDOWN POINTS

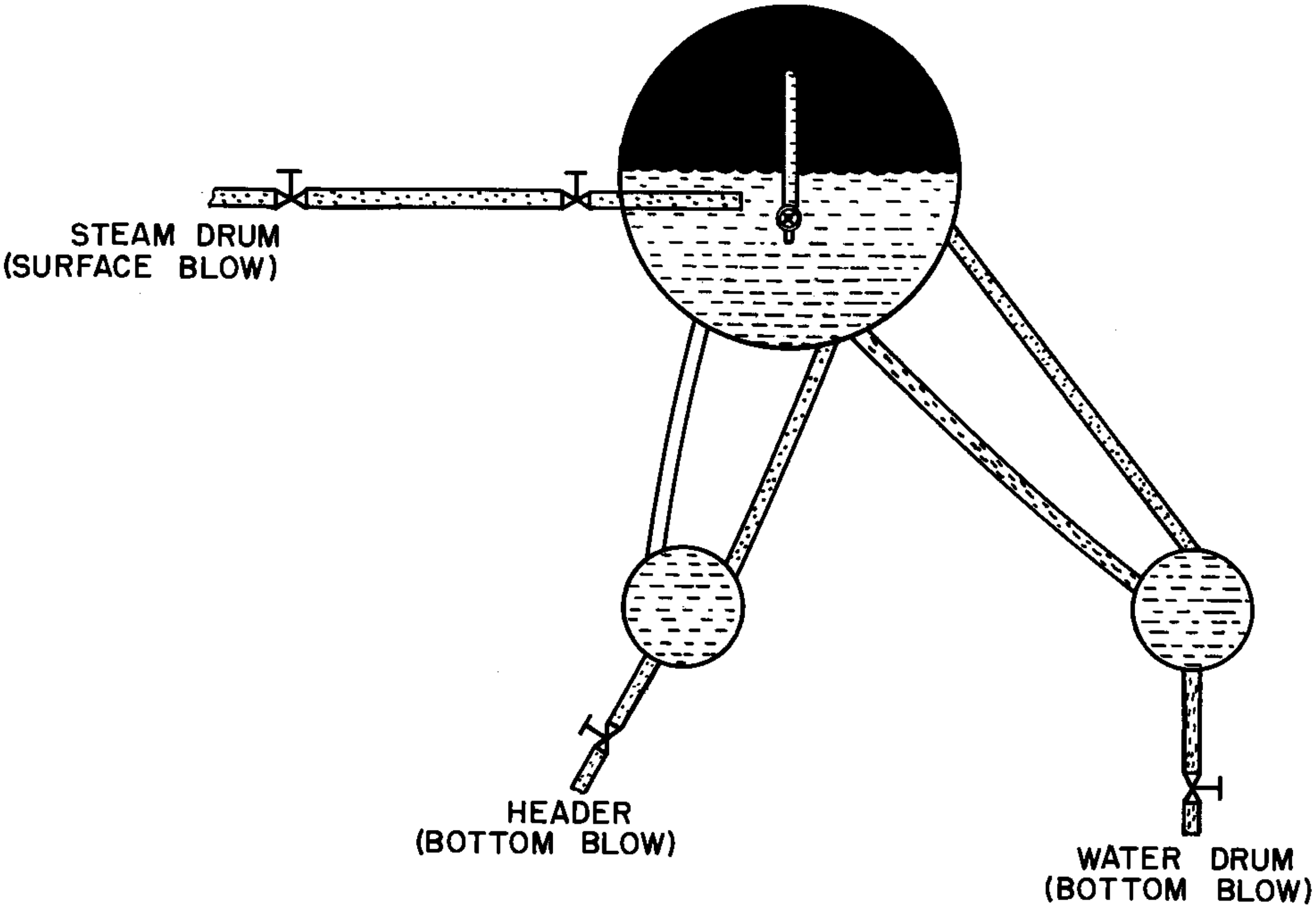


Figure 9560-13. Boiler blowdown points.

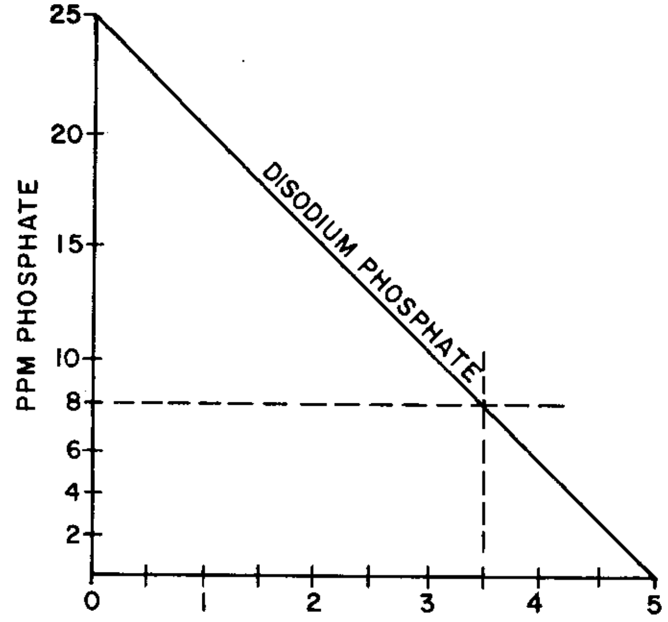


Figure 9650-14. Ounces of treatment per 1000 gallons to raise the pH value to 11.0.

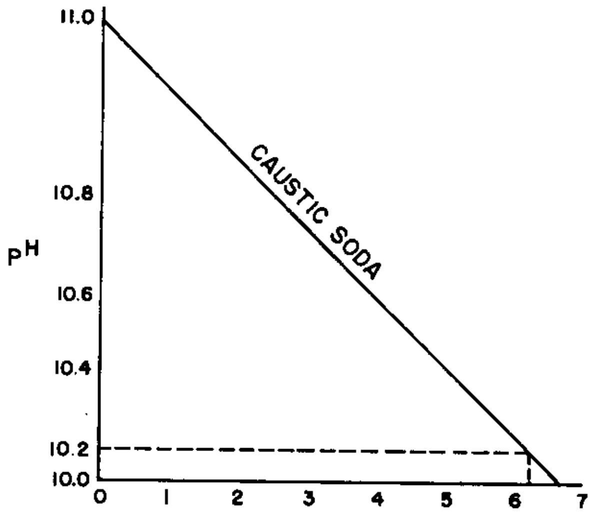


Figure 9560-15. Ounces of treatment per 1,000 gallons to raise phosphate content to 25 ppm.

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 standord 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 phosphote.

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

	Phosphate-Starch Addition		
Gallons Untreated Water Added	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.

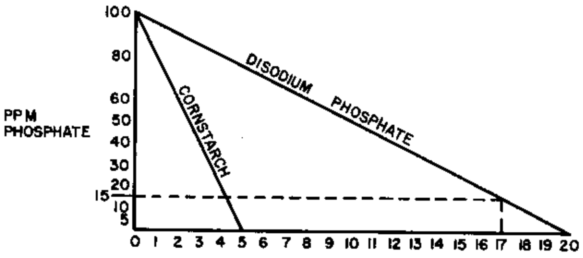


Figure 9560-16. Ounces of treatment per 1,000 gallons to raise phosphate to 100 ppm.

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.

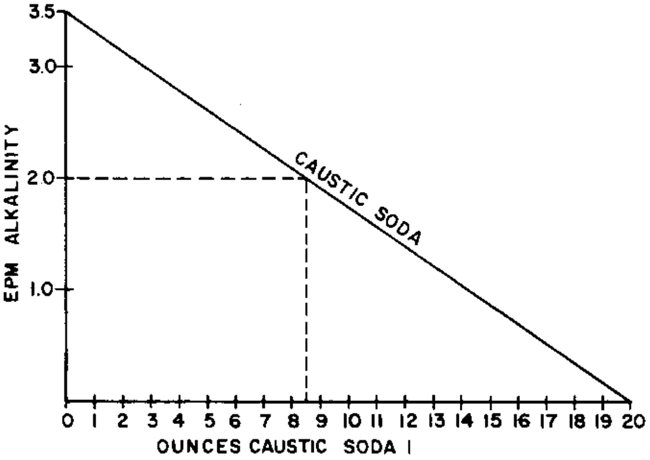


Figure 9560-17. Ounces of treatment per 1000 gallons to raise the alkalinity content to 3.5 epm.

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-bay.

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 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.

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

7/1/67

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 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

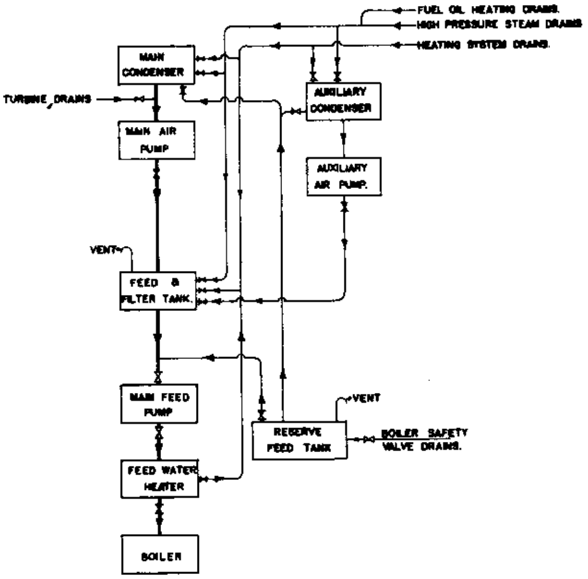


Figure 9560-6

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.

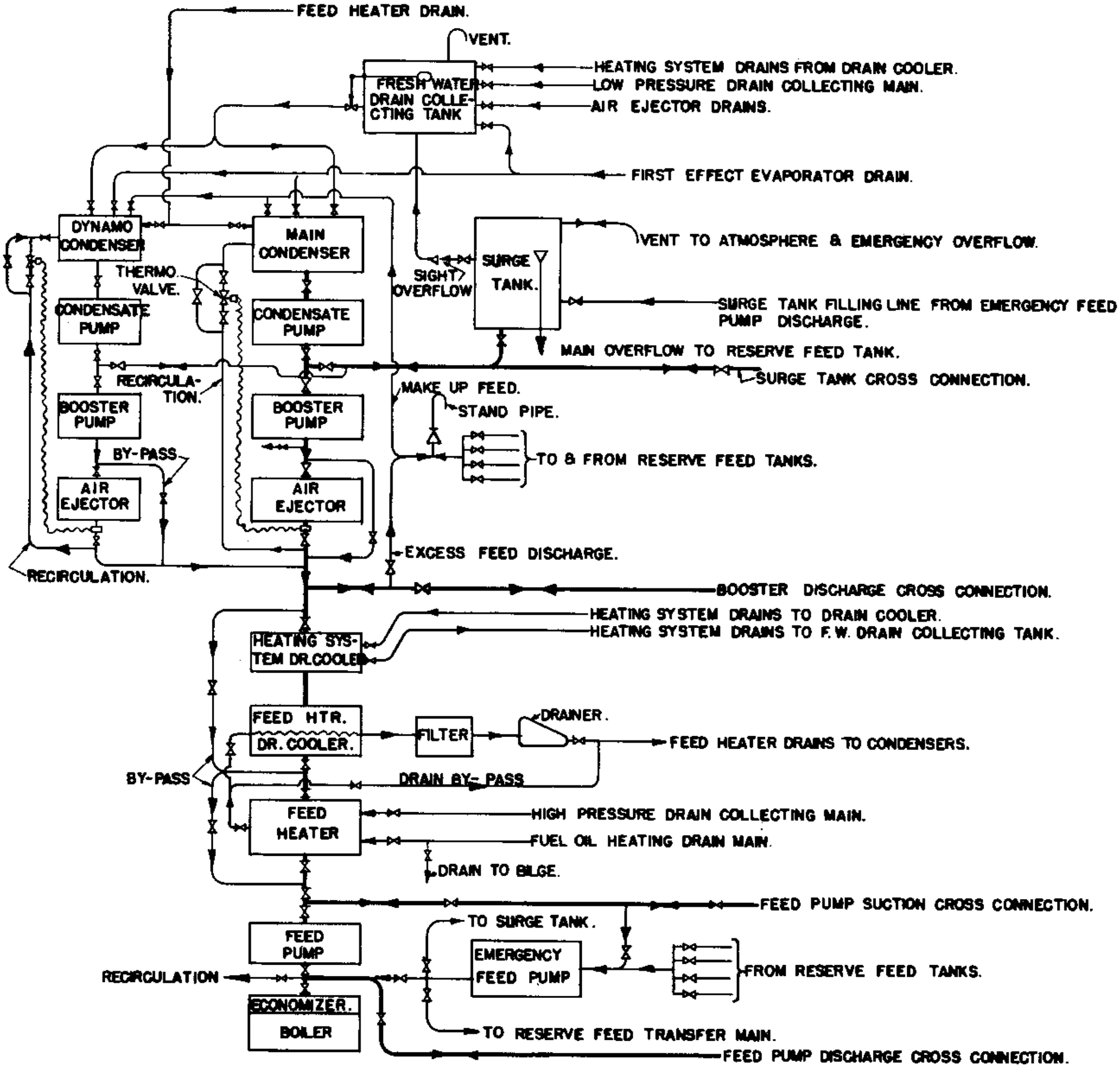


Figure 9560-7

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 semienclosed 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 semienclosed 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, contaminotion 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 normolly 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 backwords.

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.

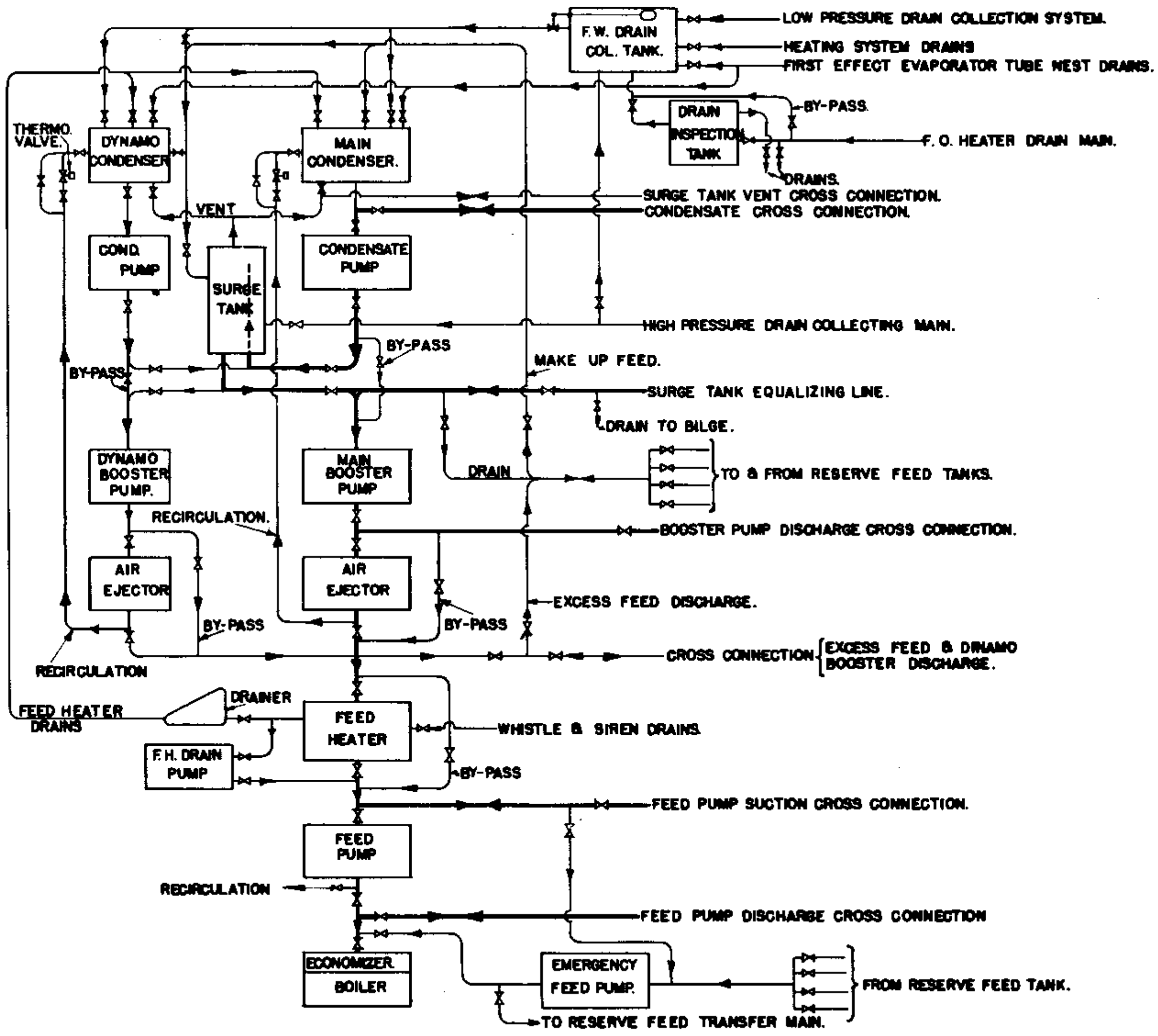


Figure 9560-8

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 condensote 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.

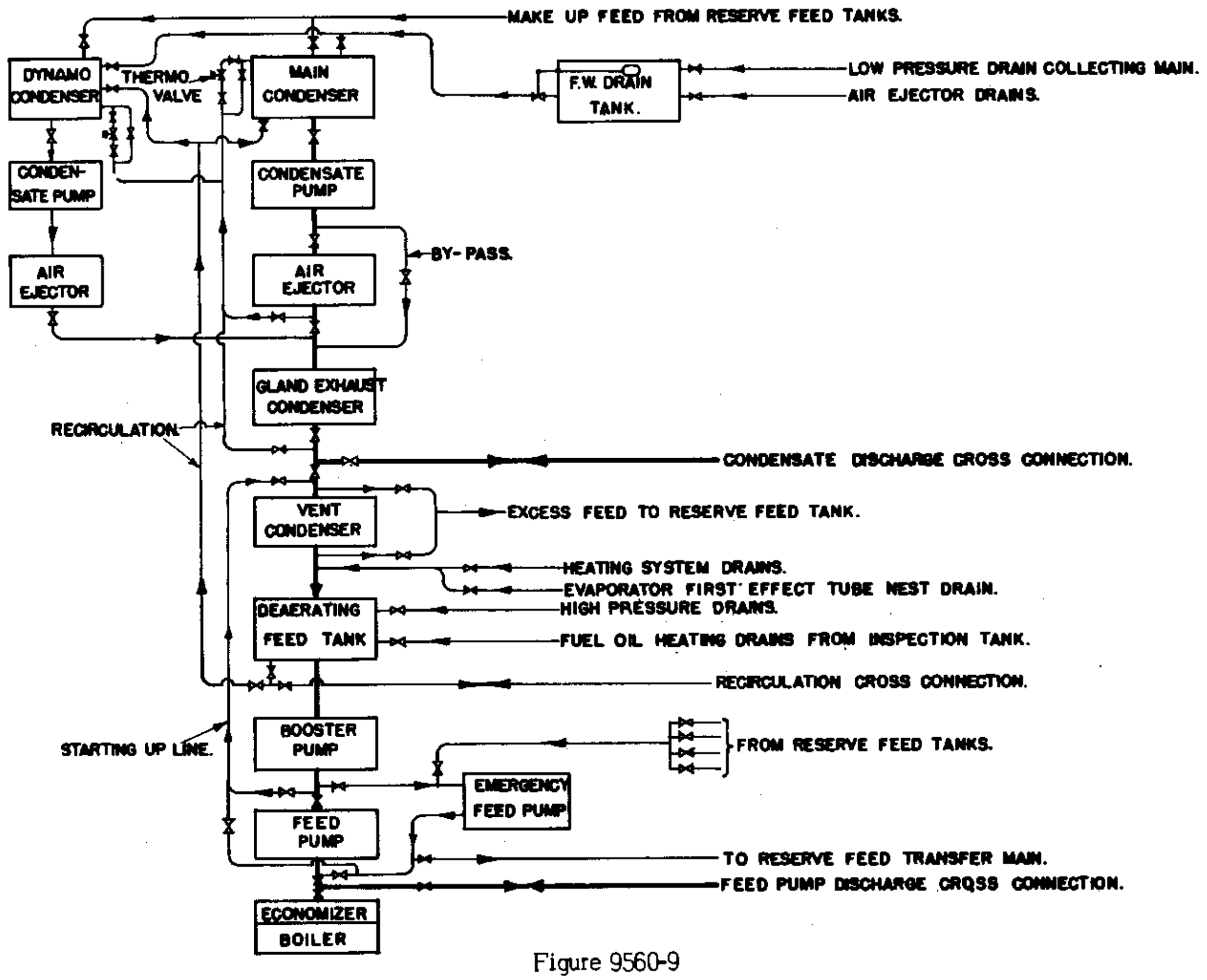


Figure 9560-9

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

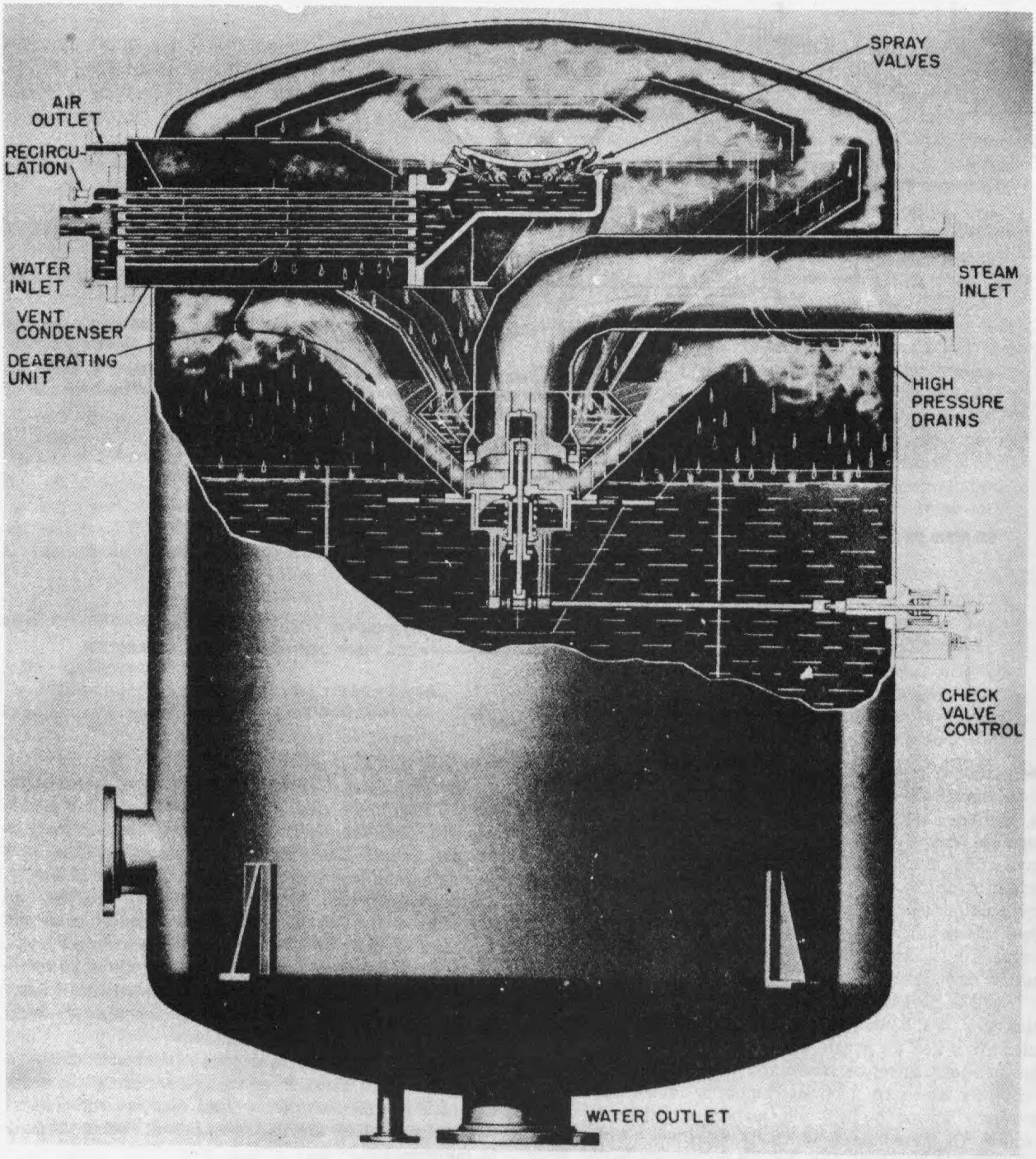
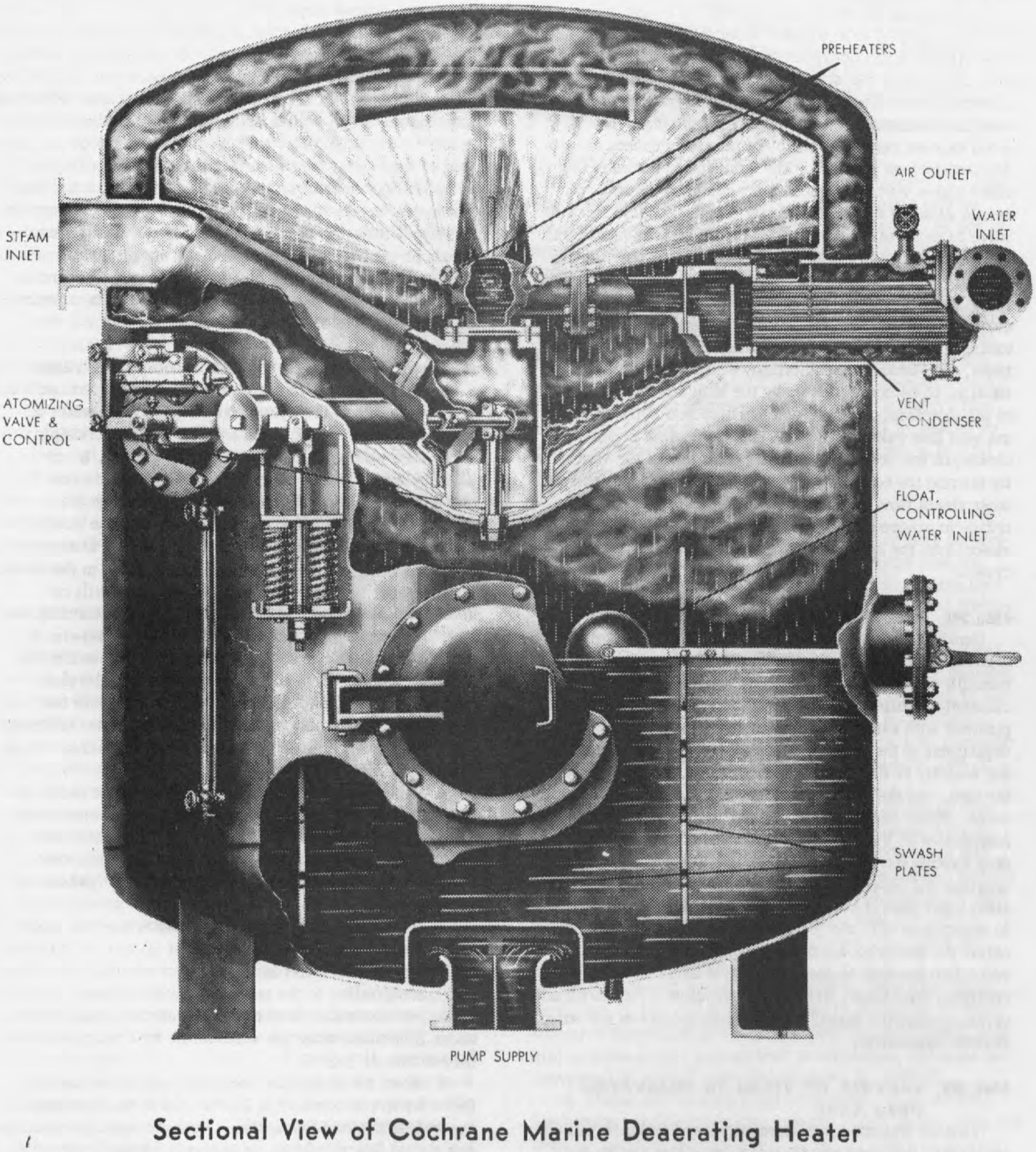


Figure 9560-10. Sectional View of Cochrane Marine Deaerating Heater.



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-

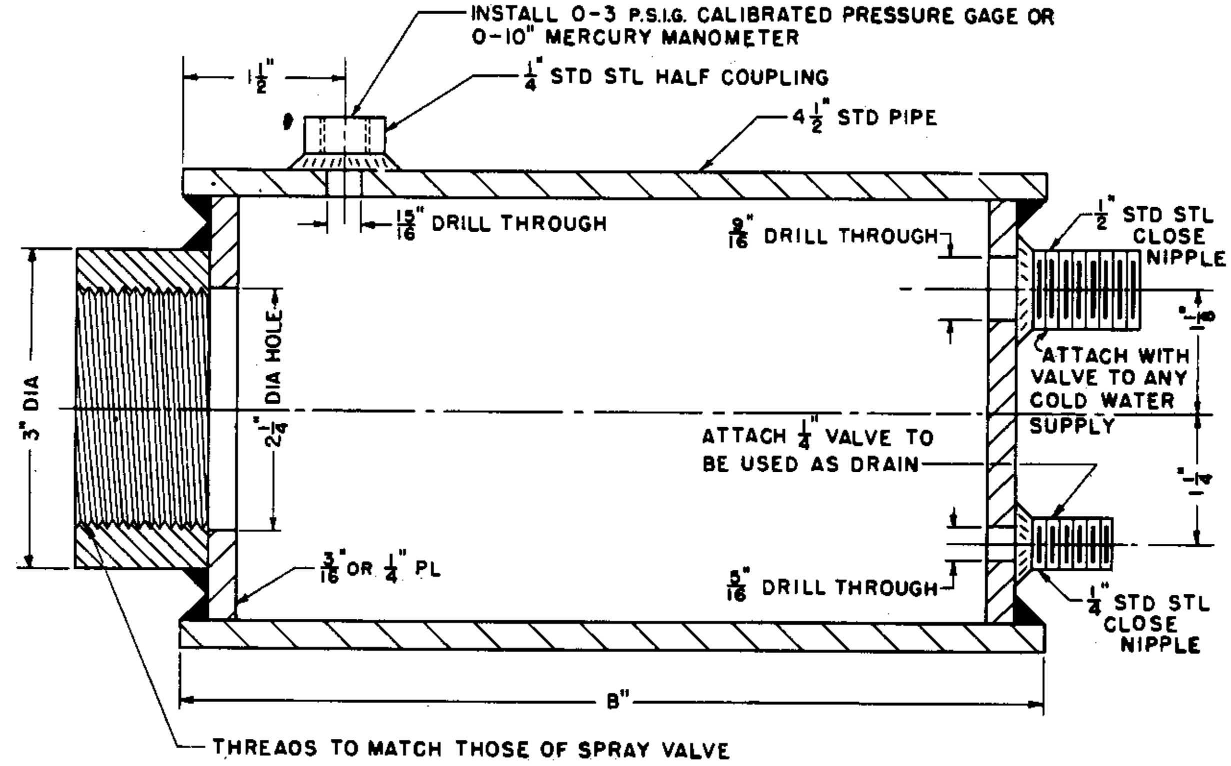


Figure 9560-12

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:

CAUTION TEMPORARY STRAINER
INSTALLED REMOVE PRIOR TO
FULL POWER RUNS