REVISION 2

NAVAL SHIPS' TECHNICAL MANUAL

CHAPTER 531

DESALINATION
VOLUME 1 LOW-PRESSURE
DISTILLING PLANTS

THIS CHAPTER SUPERSEDES CHAPTER 531, VOLUME 1 DATED 1 JULY 1988

PUBLISHED BY DIRECTION OF COMMANDER, NAVAL SEA SYSTEMS COMMAND

1 SEP 1999

NAVSEA TECHNICAL MANUAL CERTIFICATION SHEET 1 of 1

Certification Applies to: New Manual ☐ Revision ☒ Change ☐

Applicable TMINS/Pub. No. S9086–SC–STM–010/CH–531R2

Publication Date (Mo, Da, Yr) September 1999

Title: NSTM Chapter 531, Volume 1, Low–Pressure Distilling Plants

TMCR/TMSR/Specification No:

CHANGES AND REVISIONS:

Purpose: Side bars in the outside margin indicate changes since the last revision. This chapter was reformatted to support conversion to SGML and electronic distribution. Technical changes requested by the Life Cycle Manager have been incorporated but the chapter has not yet been approved by the Technical Authority.

Equipment Alteration Numbers Incorporated:

TMDER/ACN Numbers Incorporated:

Continue on reverse side or add pages as needed.

CERTIFICATION STATEMENT

This is to certify that responsible NAVSEA activities have reviewed the above identified document for acquisition compliance, technical coverage, and printing quality. This form is for internal NAVSEA management use only, and does not imply contractual approval or acceptance of the technical manual by the Government, nor relieve the contractor of any responsibility for delivering the technical manual in accordance with the contract requirement.

Authority	Name	Signature	Organization	Code	Date
Acquisition					
Technical					
Printing Release	Digital Media Publishing				

Certification Sheet

TABLE OF CONTENTS

TABLE OF CONTENTS - Continued

Chapter/Paragraph Page

TABLE OF CONTENTS - Continued

Chapter/Paragraph Page

TABLE OF CONTENTS - Continued

Chapter/Paragraph Page

TABLE OF CONTENTS - Continued

LIST OF TABLES

LIST OF ILLUSTRATIONS

NOTE

THIS CHAPTER HAS BEEN REFORMATTED FROM DOUBLE COLUMN TO SINGLE COLUMN TO SUPPORT THE NSTM DATABASE. THE CONTENT OF THIS CHAPTER HAS NOT BEEN CHANGED.

CHAPTER 531

VOLUME 1 DESALINATION, LOW-PRESSURE DISTILLING PLANTS

SECTION 1.
GENERAL

531-1.1 BACKGROUND

531-1.1.1 FUNCTION. Marine distilling plants are designed to supply all shipboard freshwater requirements, including potable water for drinking and hotel services and high-purity boiler feedwater for steam propulsion plants. The distilling plant uses normal seawater, typically containing 35,000 parts per million (ppm) of total dissolved solids, and produces a distillate of 2.3 ppm of chlorides or less. The most important requirement of a distilling plant is reliability.

531-1.1.2 DEFINITIONS. Terms applicable to all types of distilling plants are defined in Appendix A.

531-1.2 TYPES OF PLANTS

531-1.2.1 GENERAL. Three general types of distilling plants are installed in naval ships. These are the vapor-compression, low-pressure steam (flash, submerged tube and basket), and heat recovery types. The major differences among the three types of plants are the form of energy used for operation and the pressure under which distillation takes place. Vapor-compression distillers use electrical energy for heaters and compressors, and boil the seawater feed near atmospheric pressure. Low-pressure steam units use steam from the auxiliary exhaust steam system or the auxiliary steam system as a heat source; heat recovery units use diesel engine cooling jacket water for this purpose. Both these plants operate at a higher vacuum (and consequently lower temperature) than the vapor-compression type.

531-1.2.1.1 Vapor-compression plants are used on small, diesel-powered surface ships and submarines. Low-pressure steam units are used on steam and gas turbine-powered surface ships and submarines; heat recovery units are used on diesel and gas turbine-powered surface ships.

531-1.2.2 LOW-PRESSURE STEAM. There are three types of low-pressure steam-distilling plants: submerged-tube, vertical-basket, and flash. The first two types are similar, differing only in the kind of heat transfer surface used to boil the seawater feed. In the flash-type plant, the seawater feed is not boiled but is flashed to vapor by a pressure drop. Submerged-tube and vertical-basket distillers are discussed in Section 2 of this chapter. Heat recovery units are also discussed in Section 2. Flash plants are covered in Section 3, and the appendixes contain information common to all low-pressure steam units.

531-1.2.3 SUBMARINE DISTILLING PLANTS. All low-pressure steam distilling plants operate according to the same principles, but they vary in actual design, even within a single plant type (such as flash, submerged-tube, and so forth). The circuits and operating procedures described in this chapter of the NSTM apply mainly to surface ship distilling plant design. The general principles described here also apply to submarines. For more detailed information on the design of submarine distilling plants, refer to NAVSEA T9500-AA-PRO-050, **NAVSEA Design Practices and Criteria Manual for Submarine Steam Distilling Plant Systems.**

SECTION 2.

SUBMERGED TUBE AND VERTICAL-BASKET DISTILLING PLANTS

531-2.1 DESCRIPTION

531-2.1.1 GENERAL. Installations of low-pressure submerged-tube and vertical-basket distilling plants vary considerably in different ships. The basic principles are the same in all cases. The only significant difference between the two plants is the type of heat transfer surface used. In submerged-tube plants steam is passed through tube bundles, boiling the surrounding water. In vertical-basket plants the heating steam is contained in deeply corrugated baskets, with the boiling occurring outside the basket between the corrugations. A diagram of a low-pressure submerged-tube distilling plant consisting of one triple-effect unit is shown in Figure 531-2-1. This type of unit is described in paragraphs 531-2.1.2 through 531-2.1.3.8 which also apply to vertical-basket plants.

531-2.1.2 COMPONENTS. The distilling plant shown in Figure 531-2-1 consists of three evaporating units working in triple effect. Major components include a distiller condenser, distillate cooler, circulating-water pump, air ejector, air ejector condenser, feed treatment injection system, evaporator feed pump, brine overboard pump, distillate pump, first-effect tube nest drain pump, vapor feedheaters, drain regulators, distillate meter, salinity-indicating system, solenoid-operated bypass valve, and piping, valves, and fittings.

531-2.1.3 CIRCULATING SYSTEMS. The piping systems of submerged-tube and vertical-basket distilling plants are divided into seven circulating systems as follows:

a. Generating steam circuit

b. Vapor circuit

c. Distillate circuit

d. Air-removal circuit

e. Circulating-water circuit

f. Evaporator feed circuit

g. Brine circuit

531-2.1.3.1 Overview. These circulating systems, together with the necessary vent and drain connections to the plant components, make up the complete piping system. The functions of the circulating systems and plant components are described in the following paragraphs.

531-2.1.3.2 Generating Steam Circuit. The generating steam for the distilling plant is obtained from the auxiliary exhaust line and passes through a pressure-regulating valve. This valve is adjusted to maintain a fixed steam pressure upstream of an orifice in the line to the evaporator first-effect tube bundle heat exchanger. A pressure gage is installed ahead of the regulating valve; a compound gage is installed ahead of the orifice; and a relief valve, compound gage, and thermometer are installed on the steam head of the first effect to maintain the quantity and quality of the generating steam. The other major components of the generating steam circuit are as follows:

a. Desuperheater Connection. When the pressure of steam is reduced in the regulating valve, the steam temperature remains relatively constant on both sides of the valve. On the downstream side of the valve, however, the pressure is lower than on the upstream side, resulting in the downstream (lower pressure) steam becoming superheated. This superheated steam is not very useful for heat transfer because the phase change (vapor to liquid) during condensation releases much more heat than can be produced by cooling the superheated steam. This superheat leads to more scale formation because of the higher temperature. To prevent this undesirable condition, a desuperheater nozzle is installed in the steam supply line between the regulating valve and the entrance to the first-effect heat exchanger. Hot water is taken from the discharge of the first-effect drain pump and sprayed through the desuperheater nozzle into the supply line to reduce the steam superheat. Temperature is maintained about 5°F to 10°F above the saturation temperature corresponding to the pressure in the first-effect heat exchanger. The optimum cycle operation is at saturated steam conditions, since latent heat is not given off until that point is reached.

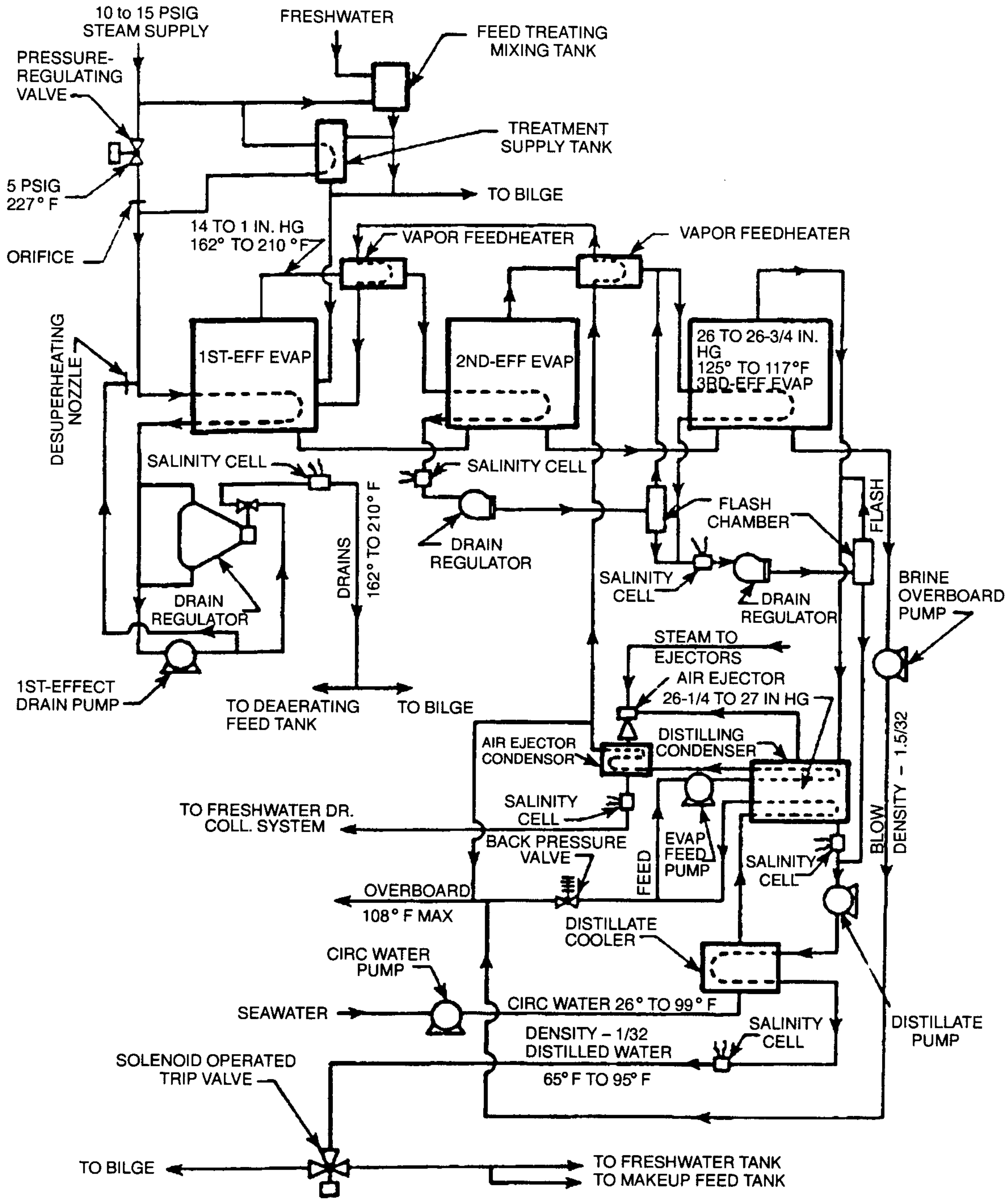


Figure 531-2-1 Diagram of Triple-Effect Submerged-Tube Distilling Plant

b. Control Orifice. An important characteristic of an orifice is that a constant quantity of steam will pass through the orifice regardless of the pressure on the inlet side (as long as the absolute pressure on the outlet side is no more than 58 percent of that on the inlet side). The heating effect of the steam in the first-effect heat exchanger is due to the latent heat of condensation. Since this latent heat varies only 3 percent between 7 pounds per square inch absolute (psia) and 20 psia, it follows that if a constant quantity of steam is condensed, a constant quantity of vapor will be produced. Do not increase unit capacity when tubes are fouled by increasing orifice size or steam pressure, as this will increase scaling. A steady increase in absolute pressure within the first-effect heat exchanger indicates fouling of the exterior surface. An orifice is located between the reducing valve and the inlet to the first-effect heat exchanger. This orifice is designed to pass the quantity of steam required to produce the normal capacity of the plant. When starting out with a clean surface, the pressure inside the heat exchanger will be that corresponding to a temperature just high enough to transfer the amount of heat needed (to produce rated capacity) through the heat exchanger walls to the seawater. As the heat exchanger becomes fouled, a higher steam temperature will be required. The orifice permits this temperature increase by automatically increasing pressure without any increase in steam flow and, as a result, maintains a constant plant capacity. Orifice sizes for submerged-tube plants are listed in Table 531-2-1. For orifice sizes on vertical-basket plants, refer to the manufacturer's technical manual.

Table 531-2-1 ORIFICE SIZES FOR SUBMERGED-TUBE DISTILLING PLANT

Nominal Size of Plant (Gallons per Day)	Diameter of Orifice	
	100 Percent Rating (Inches)	130 Percent Rating (Inches)
4,000	1-5/64	1-7/32
8,000	1-17/32	1-3/4
10,000	1-3/4	1-31/32
12,000	1-7/8	2-1/8
20,000, Double-Effect	2-3/8	2-11/16
20,000, Triple-Effect	2-1/32	2-5/16
30,000	2-1/2	2-13/16
40,000	2-25/32	3-5/32
50,000	3-25/32	4-11/32

c. First-Effect Heat Exchanger. The generating steam is condensed in the first-effect heat exchanger and gives up its latent heat to the surrounding feed in the first-effect shell. The condensate from the first-effect heat exchanger may be discharged to the main condenser, to the freshwater drain collecting system, or to waste, depending on condensate purity and system configuration.

d. Drain Regulator. A drain regulator is provided in the condensate line to prevent steam from blowing through the heat exchanger before giving up its latent heat. This drain regulator consists of a body and cover enclosing a balanced cage or rotary valve operated by a ball float.

e. First-Effect Heat Exchanger Drain Pump. A drain pump is usually installed to discharge to the condensate system or to the low-pressure drain system. Atmospheric or trapped drains would prevent the first-effect heat exchanger from operating at pressures below atmospheric. To permit operation if the pump fails, drains may be connected to the main or auxiliary condenser. If the condensate becomes contaminated, the drain pump discharge may be directed to waste.

531-2.1.3.3 Vapor Circuit. The steam generated in the evaporator shells when the feed evaporates on contact with the heat exchanger is referred to as vapor. The important components of the vapor circuit are described below.

a. Vapor Separators. Vapor contains small particles of unevaporated, salt-laden feed. These particles are removed from the vapor by various types of vapor separators, including baffles, hooked vanes, cyclonic separators, and woven-wire-mesh demisters. Vapor separators are located above the water surface in the evaporator shells.

b. Vapor Feedheaters. After passing through the vapor separators on its way to the succeeding heat exchanger, the vapor generated in each evaporator is partially condensed on the tube surfaces of the vapor feedheater, giving up latent heat to the feed passing through the tubes of the heater.

c. First-Effect Vapor Circuit. The vapor generated in the first effect passes through its vapor separator and vapor feed heater to the heat exchanger of the second effect, where it is condensed, giving up its latent heat to the feed in the second-effect shell.

d. Second-Effect Vapor Circuit. The vapor generated in the second effect passes through a vapor separator and vapor feedheater to the heat exchanger of the third effect, where it is condensed, giving up its latent heat to the feed in the third-effect shell.

e. Third-Effect Vapor Circuit. The vapor generated in the third-effect shell passes through a vapor separator to the distiller condenser.

f. Distiller Condenser. The condensing tubes nearest the incoming vapor from the third-effect evaporator are used as a feed-heating section of the condenser. The vapor is partially condensed in this section, thereby heating the feed that circulates through the tubes. The remainder of the vapor is condensed in the condensing section. In some designs the distiller condenser is built into the shell of the last effect.

g. Flash Tank. The flash tanks collect the hot drain discharge from the second- and third-effect heat exchangers and allow it to flash partially to steam as the pressure is reduced by drain regulators. This prevents flashing in the distillate pump, which is downstream of the distiller condenser.

531-2.1.3.4 Distillate Circuit. The vapor formed in the shell side of the first effect is condensed in the tube side of the second-effect heat exchanger. Likewise, the second-effect vapor is condensed in the third-effect heat exchanger, and third-effect vapor is condensed in the distiller condenser. These three sources of distillate constitute the freshwater output of the plant.

a. Second-Effect Drains. The distillate from the second effect heat exchanger passes through a drain regulator that maintains a water seal between the second-effect heat exchanger and the second-effect flash tank. In passing through the drain regulator, the distillate pressure is reduced from that in the second-effect heat exchanger drains to that in the third-effect heat exchanger. This reduced pressure causes a certain amount of the distillate to flash into vapor. This vapor is separated from the distillate in the second-effect flash tank and led to the third-effect heat exchanger. Here it is condensed, giving up its latent heat to the feed in the third-effect shell. The distillate from the second-effect flash tank is led to the third-effect heat exchanger drain line. The second-effect flash tank is sometimes omitted, and the combined vapor and distillate discharge directly to the third-effect heat exchanger from the drain regulator.

b. Third-Effect Drains. The distillate from the third-effect heat exchanger, combined with that from the second-effect flash tank, flows through the third-effect drain regulator to the third-effect flash tank. Any vapor liberated by the pressure reduction from that in the third-effect heat exchanger to that in the flash tank is directed to the condenser. Here it is condensed along with the vapor from the third effect.

c. Distiller Condenser Drains. The distillate from the distiller condenser combines with the discharge from the third-effect flash tank before entering the distillate pump. (In some installations, they combine upstream of the third-effect flash tanks.)

d. Distillate Pump. This pump takes suction from the combined drains of the third-effect flash tank and distiller condenser and discharges distillate through the distillate cooler.

e. Distillate Cooler. The distillate cooler cools the distillate produced by the plant to within 105°F of the incoming seawater.

f. Distillate Water Meter. A positive displacement totalizing-type freshwater meter is installed, giving direct readings in U.S. gallons. A bypass connection is provided around the meter.

g. Solenoid-Operated Trip Valve. A salinity cell in the distillate line downstream of the distillate cooler actuates a solenoid-operated trip valve that routes the entire plant output to waste when predetermined salinity limits are exceeded. This safety device is installed to prevent contamination of the freshwater and reserve feed systems.

531-2.1.3.5 Air-Removal Circuit. Air and noncondensable vapors enter the plant dissolved in the evaporator seawater feed. As the feed is heated, the dissolved air is liberated and collects in various parts of the plant. Air also enters the plant with the generating steam and through various small leaks at pump glands and vacuum joints. Since the distiller condenser is after the last effect in the heat-flow cycle of the distilling plant, the absolute pressure in this unit is lowest, and noncondensable gases tend to collect there. To maintain the required vacuum, these noncondensable gases must be removed.

a. Air Vents. Air enters the distiller condenser with vapor from the third-effect evaporator and flash tank and through a series of lines that vent various units of the plant to the condenser. The correct operation of these vents is essential to satisfactory plant operation. Further information on air vents is contained in paragraph 531-2.2.8.3.

b. Air Ejectors. Two air ejectors are usually provided for removing the noncondensable gases that accumulate in the distiller condenser. Under normal conditions the distilling plant requires only one of these ejectors. The second ejector is available as a spare or for use under abnormal conditions. For a detailed description of air ejectors see **NSTM Chapter 254, Condensers, Heat Exchangers, and Air Ejectors.**

c. Air Precooler. The air ejector suction piping is connected to the air precooling section of the distiller condenser. This section comprises about 8 percent of the condenser cooling surface. It is separated from the rest of the tubes by an air baffle. The air precooler cools and removes water vapor from the air to be handled by the ejectors.

d. Air Ejector Steam. The motive steam for the distiller air ejectors is supplied by the auxiliary steam line (or another source that can ensure an ample supply of dry steam at the pressure for which the air ejector is designed). The ejectors are usually designed to operate with steam pressure of 150 pounds per square inch gage (psig) or less. Steam strainers are usually provided in the steam supply line ahead of the reducing valve and ahead of each air ejector nozzle. A pressure gage and relief valve are usually installed in the steam supply piping between the reducing valve and the air ejectors. Steam pressure at the air ejector should be maintained within 10 to 15 pounds per square inch (psi) above the design operating pressure shown on the name plate. Never allow the pressure to drop below the name plate value.

e. Air Ejector Condenser. The motive steam entering the air ejector compresses the noncondensable vapors there to a pressure slightly above atmospheric. The mixture of steam and air then condense and cool in the air ejector condenser. Here the vapor gives up its latent heat to the evaporator feed passing through the condenser tubes. The noncondensable gases are vented to the atmosphere. The condensate returns to the freshwater drain collecting system (in submarines this condensate is dumped to the bilge).

531-2.1.3.6 Circulating-Water Circuit. The distiller condenser circulating-water pump takes suction from the sea and discharges through the distillate cooler and the distiller condenser. The cooling water usually makes one pass through the tubes of the distillate cooler and two through the tubes of the distiller condenser. The cooling water is then discharged overboard, usually through a back-pressure valve set to maintain a back pressure of about 5 psig.

531-2.1.3.7 Evaporator Feed Circuit. A portion of the seawater from the circulating water system is used as evaporator feed. This feed passes through the series of heat exchangers described earlier, thus raising the temperature of the feed and reducing the amount of steam required by the first-effect heat exchanger.

a. Evaporator Feed Pump. This pump takes suction from the circulating-water lines between the outlet from the condensing section of the distiller condenser and the spring-loaded back-pressure valve. The back- pressure valve provides a constant positive suction head.

b. Distiller Condenser Feedheater. From the feed pump, the seawater discharges into the feedheater section of the distiller condenser. Here, it picks up heat by condensing a part of the vapor from the third-effect evaporator shell.

c. Air Ejector Condenser. The feed passes through the air ejector condenser, condensing the air ejector motive steam and cooling the air and other noncondensable gases removed from the third effect. A bleedoff line leaks from the feed line at the outlet of the air ejector condenser to the circulating-water pump overboard discharge line. Flow through this bleedoff line is regulated manually to provide cooling water to the air ejector condenser during lightoff and abnormal operating conditions.

d. Second-Effect Vapor Feedheater. From the air ejector condenser, the feed passes through the second-effect vapor feedheater. Here, a part of the vapor from the second-effect shell condenses, giving up heat to the feed.

e. First-Effect Vapor Feedheater. This is the last in the series of heat exchangers in the feed system. It operates in the same manner as the second-effect heater.

f. Feed Control. Feed to the evaporator is usually controlled by manually operated feed valves.

g. Feed Distributing Pipes. Feed enters the evaporator shell through a connection well below the working water level. Most evaporators have internal perforated feed pipes to distribute the feed evenly in the shell below the heat exchanger.

h. Feed Treatment System. This system consists of a mixing tank and a proportioning pump. The feed treatment compound is injected into the distilling plant feed system by the proportioning pump or by vacuum drag to the first-effect shell. This system is described in more detail in paragraph 531-2.2.7.

i. Proportioning Pump. This is an electrically operated, adjustable-stroke, reciprocating pump. The speed of the pump is constant, and its capacity is varied by adjusting the length of the stroke.

531-2.1.3.8 Brine Circuit. After being partially evaporated in the first-effect shell, the feed (now termed brine) enters the second and then the third effects, where it is evaporated further. The brine is introduced into the second and third effects through perforated pipes similar to those used for feed distribution in the first effect. The remaining brine is pumped overboard from the third effect.

a. Interstage Feed. The pressure differential between the effects is used to transfer the brine through a manually controlled regulating valve from the first effect to the second effect, and from the second effect to the third.

b. Brine Overboard Pump. This pump takes suction from the third-effect shell and discharges into the overboard discharge line of the distiller circulating pump. On some of the submerged-tube evaporators, a Macomb-type strainer is installed in the brine pump suction line. Because of the relatively large quantities of small pieces of scale in the brine, basket-type distilling plants usually use semiopen impeller brine pumps. These pumps allow scale to pass through so that no strainer is necessary in the brine pump suction line. To permit rapid dumping of the first- and second-effect shells, there are also direct suction connections from the brine overboard pump to these shells. Since these connections are not used for normal operation, they usually have locked valves. This pump operates under a vacuum on the suction side, and the gland shall be sealed by a gland seal line from the discharge of the circulating pump. Never use brine pump discharge for a source of gland seal water. To prevent the pump from becoming vapor bound, vent its suction to the last-effect shell.

c. Brine Density Control. Average seawater contains approximately 1 part of dissolved sea salt to 32 parts of water (1/32 by weight). The ideal brine density from the last effect should be 1-1/2 times the density of average seawater, or 1.5/32. Lower brine density results in poor plant efficiency; higher brine density causes excessive scale formation on heat transfer surfaces. Brine density is controlled by adjusting the rate of feed and brine flow. Test connections are provided in the brine overboard line to permit taking brine samples for the salinometer test. Secure the brine dilution and brine pump gland sealing line before taking the brine sample. Basket-type distilling plants usually have a brine dilution line. Diluting the brine reduces the rate of scale buildup in the brine overboard system. Where the dilution line connects at the suction side it also lowers the temperature of the brine to reduce the possibility of brine pump cavitation.

531-2.1.4 DOUBLE-EFFECT PLANTS. Some smaller distilling plants have only two effects, rather than the three shown on Figure 531-2-1. The functions of the individual components are identical in triple-and double-effect plants, with the following minor differences:

a. Evaporation takes place in two shells rather than three.

b. Evaporator feed pumps are not used, since with the shorter feed circuit the back pressure provides the regulating valve with enough feed.

531-2.1.5 LEVEL CONTROLLERS. Two types of level controls are used to maintain proper levels in submerged-tube evaporator shells: weir level control and manual control.

531-2.1.5.1 Weir Level Control. In some plants the water level is automatically maintained by weir-type level controllers. An adjustable-height weir is located at the brine outlet from each shell, and the feed from each effect to the next consists of the brine that spills over the weir (that is, the excess of feed over evaporation in each effect). Some plants have fixed weirs.

531-2.1.5.2 Manual Control. In some plants the water level is manually controlled by adjusting the feed valves for each effect and the bypass valve at the brine pump discharge.

531-2.1.5.3 Basket-Type Plants. When the feed rate is correctly adjusted, the water level in basket-type plants is controlled by the rate of evaporation. Never try to adjust these levels manually.

531-2.1.6 SALINITY-INDICATING SYSTEM. Salinity-indicating systems are installed in distilling plants to ensure that the plants produce sufficiently pure, mineral-free water. Salinity-indicating systems have paired electrodes (called salinity cells) inserted into the freshwater flow at strategic points. Since the conductivity of water is directly related to the amount of salt in solution, measuring the current flowing between the electrodes indicates the salinity of the water.

531-2.1.6.1 Cell Locations. Salinity cells are installed in the freshwater circuit at each point where contamination is possible. It is thus possible to determine leak or contamination sites by checking salinity at various points in the system. The actual cell locations are shown on Figure 531-2-1 and are discussed further in paragraphs 531-2.3.2.3 through 531-2.3.2.3.5.

531-2.1.6.2 Indicating Panel. The various cells are connected to a salinity-indicating panel on which are mounted a selector switch, a cell test switch, and a meter calibrated to read directly in equivalents per million (epm) of chlorides or in grains of sea salt per gallon. Since the conductivity of water also varies with temperature, in some plants a calibrating device is mounted on the panel to correct for different temperatures. Salinity cells in the most recently built plants are self-compensating for temperature, so no calibrating device is required.

531-2.1.6.3 Trip Valve Control. The salinity cell at the end of the freshwater circuit (downstream of the distillate cooler) connects directly to the solenoid-operated trip valve. This valve automatically routes plant output to waste when its salinity cell detects high salinity. On some plants a dump valve is located in the condensate circuit.

531-2.2 OPERATION

531-2.2.1 GENERAL INSTRUCTIONS. The principal factors that control low-pressure distilling plant output are shown graphically in Figure 531-2-2. This chart indicates the way these factors affect one another and how they affect the overall performance of the plant and its output. The location of the factors on this chart does not necessarily indicate their relative importance. Incorrect operation of the distillate pump, for example, may affect the output directly (in addition to affecting the condenser vacuum) as undrained distillate may, in some plants, spill back into the last effect and be re-evaporated. The temperatures and pressures noted in the following paragraphs are typical of submerged-tube distilling plants. Consult the heat balances and instructions in the distilling plant manufacturer’s technical manual to find out the temperatures and pressures found in other types of distilling plants. The general information given below, however, applies to all low-pressure steam units.

531-2.2.2 STEAM PRESSURE AND QUANTITY. Full output requires that the plant receive the correct amount of steam at the correct pressure. The orifices supplied with the plant are designed to pass the amount of steam necessary to permit operation at rated capacity with a set pressure above the orifice. Any variation of this pressure calls for an investigation of the regulating valve and the pressure-reducing valve, if installed. If both are functioning correctly and pressure cannot be maintained above the orifice, too little steam is being supplied to the plant.

531-2.2.3 FIRST-EFFECT TUBE NEST VACUUM. Current operating practice for submerged-tube distilling plants requires a first-effect tube nest pressure range of from 14 inches mercury (Hg) vacuum with clean tube bundles up to about 3 inches Hg with scaled tube surfaces. The installed heating surfaces are adequate to ensure 100-percent rated capacity within this pressure range if the plant is in satisfactory operating condition, free of air leaks, and the air ejector is supplied with enough dry steam at the correct pressure. To ensure minimum scale formation and to maintain full capacity for long periods, the vacuum in the first-effect tube nest shall be as high as possible. Figure 531-2-2 shows that the primary factors affecting the first-effect tube nest vacuum are:

a. Air leakage

b. Water levels in evaporator shells

c. Proper venting of evaporator tube nests

d. Scale or other deposits on evaporator tubes

e. Draining of evaporator tube nests.

531-2.2.3.1 Tube Deposits. Reduction in the first-effect tube nest vacuum due to any factor other than deposits on tube surfaces, shall be eliminated. Maintaining the first-effect tube nest vacuum as high as possible will reduce the scale formation rate and greatly prolong the periods between cleanings. If the distilling plant is correctly maintained and operated, the use of evaporator feed treatment (as discussed in paragraph 531-2.2.7) will retard scale buildup on the heat exchanger surfaces. Correct operation and maintenance of the distilling plant, however, are essential to obtaining the best results from the feed treatment.

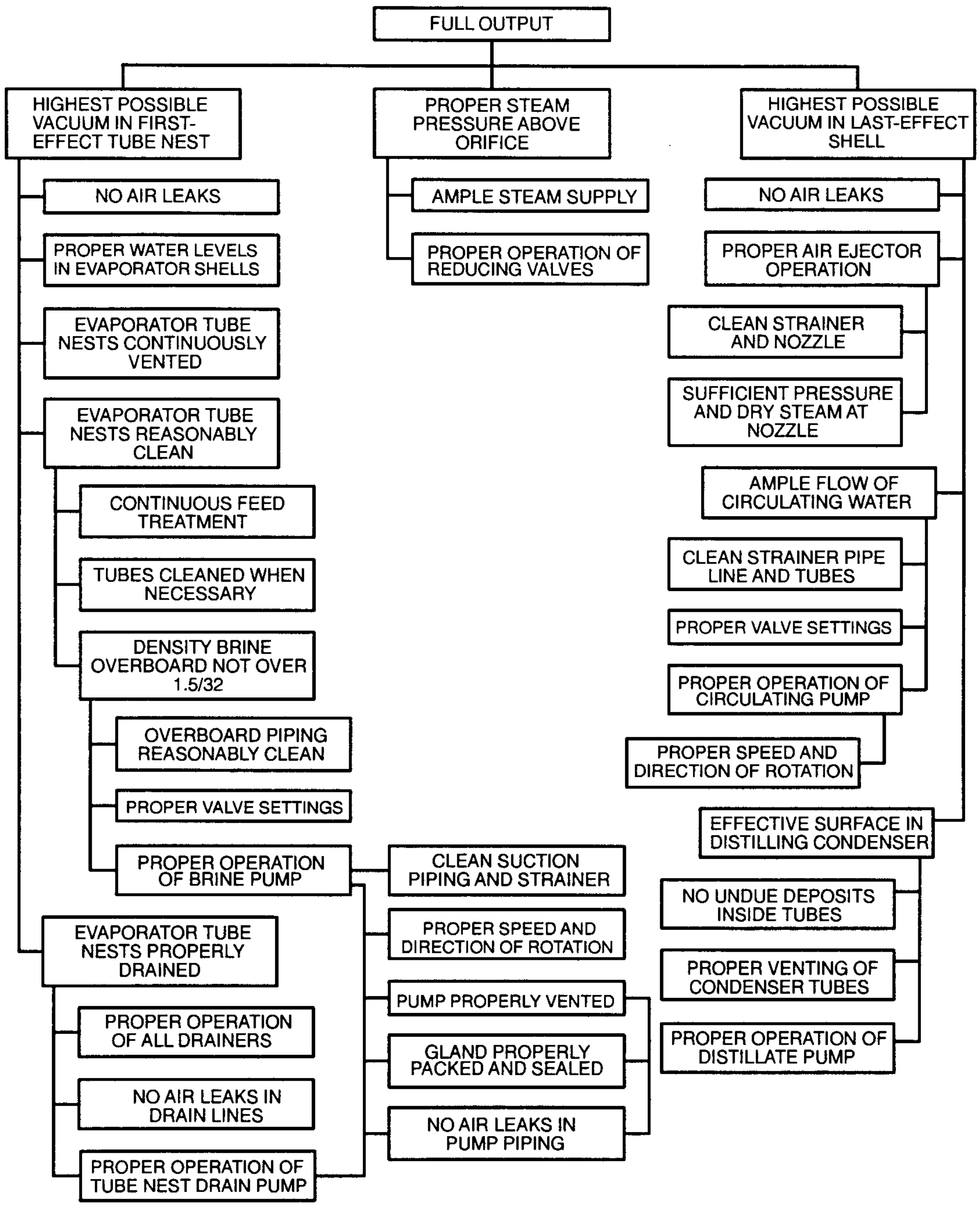


Figure 531-2-2 Factors Affecting Distilling Plant Output

531-2.2.3.1.1 Technical manual heat balance diagrams generally indicate that when starting with clean surfaces, the first-effect tube nest vacuum should be about 14 inches Hg at normal load. This vacuum will then gradually fall off as deposits accumulate on the tubes. When it is reduced to 3 inches Hg, the buildup of scale deposits must be removed to prevent a rapid reduction of plant output. Loss of first-effect tube nest vacuum due to deposits on heat exchanger tubes should be very slow and gradual. There should be no perceptible change in any one day's operation. A sudden drop or failure to obtain a vacuum of approximately 10 to 14 inches Hg when the tubes are clean and with the plant operating at rated capacity probably has one or more other causes.

531-2.2.3.2 Sight Glass Flooding. Flooding of the sight glass on any heat exchanger drain regulator indicates poor heat exchanger drainage. The fact that the sight glass has a level, however, does not necessarily indicate the right drainage, because air leaks can cause a false liquid level.

531-2.2.3.3 Low Water Level. Low water level in the first-effect evaporator shell can reduce the first-effect heat exchanger vacuum. On submerged-tube-type distilling plants the water level is controlled by handregulating the feed valve or by setting the weir level control. Plants with a fixed weir design should not have a low water problem.

531-2.2.4 LAST-EFFECT SHELL VACUUM. Most technical manual heat balance diagrams indicate that a vacuum of approximately 26 inches Hg should be obtained in the last-effect shell. This vacuum depends on (Figure 531-2-2):

a. Elimination of air leaks

b. Proper operation of air ejectors

c. Sufficient flow of circulating water

d. Effective use of heat transfer surface in the distiller condenser.

531-2.2.4.1 Air Leakage. Air leakage can be detected by hydrostatically testing the entire system. Refer to Appendix B for the hydrostatic test procedure. Sometimes air leakage can be detected if air bubbles are visible in sight glasses or gage glasses.

531-2.2.4.2 Air Ejector Operation. Faulty air ejector operation is most frequently caused by inadequate steam pressure, wet steam at the air ejector nozzle, or a clogged strainer or a clogged or worn nozzle. Faulty operation of air ejectors caused by wet steam can be corrected by installing a separator and drainer in the steam supply line. Avoid problems due to occasional drops in suction pressure by having a check valve in the air ejector suction line. Check the check valve for correct operation if first-effect vacuum is suddenly lost. The check valve, however, will not correct problems caused by a constant low steam pressure.

531-2.2.4.3 Flow of Circulating Water. In submerged-tube-type distilling plants the adequacy of circulating-water flow can be determined by temperature rise. Flow is usually insufficient if the temperature of the circulating water rises more than 20°F as it passes through the condensing section of the distiller condenser.

531-2.2.4.4 Venting. The vapor side of the distiller condenser is vented continuously by the air ejector. Vent the seawater side when starting the plant and once each watch thereafter by opening the vent valves on all saltwater heads until all the air is expelled.

531-2.2.4.5 Flooding. Failure to produce normal, full-load output (when the pressure above the orifice is 5 psig and the first-effect tube nest vacuum is several inches Hg) indicates that the condenser or one or more of the evaporator tube nests, subsequent to the first effect, has been improperly drained. Complete flooding of the flash chamber gage glass is a positive indication of poor condenser drainage. A temperature difference of more than 5° to 10°F between the last-effect shell temperature and the temperature of the distillate at the distillate cooler inlet is another indication of poor drainage.

531-2.2.5 FEED AND BRINE DENSITY. It is common practice to assume that seawater has a density of 1/32; that is, 32 pounds of seawater contain 1 pound of dissolved salts. The density of the brine in the last-effect shell depends on the amount of brine the brine pump pumps overboard. Brine density less than 1.5/32 will result in excessive heat loss and in a reduction in plant production; brine density significantly greater than 1.5/32 will cause rapid scaling.

531-2.2.5.1 Maintaining Brine Density. To maintain a constant last-effect brine density, check it hourly and adjust the brine overboard regulating and feed control valves as necessary. Feed and brine density are measured with salinometers as described in paragraph 531-2.2.8.10. Test these instruments periodically for accuracy according to the instructions in paragraphs 531-2.2.8.10 through 531-2.2.8.10.2.

531-2.2.5.2 Brine Sampling. Samples of the brine are usually obtained through a sampling cock at the brine pump discharge. To obtain a representative sample of the brine, secure the brine dilution line (for vertical-basket plants) or brine pump gland seal line (for submerged-tube plants) before sampling. Dilution or faulty pump operation is indicated when the temperature of the sample is several degrees below that of the last-effect shell.

531-2.2.6 SCALE FORMATION AND PREVENTION. The rate of scale formation is affected by the types of solids present in the feed and by the density of the brine. Although the major constituents of seawater (sodium chloride, magnesium chloride, and others) do not form scale under normal plant operating conditions, they may do so when the last-effect brine density exceeds 1.5/32. The primary scale-forming constituent of seawater, calcium carbonate, will form scale even under normal plant conditions, but the rate of scaling depends on the brine density. For these reasons, maintain the last-effect brine density at 1.5/32.

531-2.2.7 FEED TREATMENT. Another means by which to control scale formation is the use of scale preventive compound. This material helps retard scale formation and foaming in distilling plants, allowing higher plant output and less downtime over extended periods. The only authorized distiller scale preventive compound for surface ships is DOD-D-24577 (SH), Distiller Scale Preventive Treatment Formulations, available from the Navy Supply System under National Stock Number (NSN) 9G6850-00-173-7243. Ships not originally equipped with chemical injection equipment conforming to MIL-P-21397, Chemical (For Distilling Plants Naval Shipboard Use) Proportioning Unit, should install such equipment through a ship alteration (SHIPALT). The required mixing/measuring tank and proportioning injection pumps are available under NSN 1H4610-00-678-3342.

NOTE

All plants require 24 gallons of solution, regardless of plant capacity.

WARNING

Concentrated scale preventive compound is strongly alkaline. Avoid contact of the liquid with skin or eyes. Wash hands thoroughly after using. In case of contact with eyes, flush with freshwater for at least 15 minutes and report to sick bay immediately.

531-2.2.7.1 Mixing Proportions. Use 1 pint of scale preventive compound for each 4,000 gallons per day of distilling plant capacity. Combine the total amount of scale preventive compound in the mixing tank with enough freshwater to make 24 gallons of solution.

531-2.2.7.2 Injection Rate. With the proportioning pump, inject the prepared solution into the feed circuit at the rate of 1 gallon per hour. Record the mixing tank level hourly to confirm the feed rate.

531-2.2.8 OPERATING NOTES. Never force plants beyond their rated capacity except in an emergency. Such forced operation requires high pressures, and the resulting high temperatures cause more rapid scale formation and more frequent scaling of tube bundles. Also, steady operating conditions are essential for optimum results. Other factors that affect the successful operation of distilling plants are:

a. Constant generating steam pressure in first effect
b. Constant shell pressure in last effect
c. Correct venting
d. Maintenance of tight seal in drain regulator
e. Maintenance of constant brine density
f. Correct operation of pumps
g. Elimination of leaks
h. Correct operation of salinity-indicator system
i. Clean heat exchanger systems
j. Design pressure and quality steam to air ejectors
k. Fluctuating feed rate.

531-2.2.8.1 Plant Interdependence. All the elements of an operating plant are interdependent, linked by the heat and fluid flow balances. Adjustment of any one control can produce widespread effects on these balances. Rather than correcting the original condition, overcontrolling can create new conditions that need readjustment. Make adjustments singly and in small increments, with enough elapsed time between each for conditions to steady. Maintaining steady-state conditions is the key to successful operation.

531-2.2.8.2 Steam Quality. The auxiliary exhaust steam supply for the evaporator, after passing through the regulating valve, is usually slightly superheated, because of the pressure drop through the reducing valve and orifice plate. A small amount of superheat has little or no effect on operation or scale formation, but regardless of the first-effect tube nest pressure, avoid temperatures in excess of 245°F to prevent formation of hard scale. If using live steam is necessary, the steam should enter the auxiliary exhaust line through the steam side of the boiler feedheater and therefore become saturated. A desuperheater spray connection controls superheat. Take the water for desuperheating from the discharge of the first-effect heat exchanger drain pump.

531-2.2.8.3 Correct Venting. Give careful attention to the possibility that air will collect in various parts of the apparatus.

531-2.2.8.3.1 Air enters the system with steam and water, and tends to accumulate at the following points:

a. Evaporator heat exchangers and drain regulators

b. High points of the feed line

c. Water side of distiller condensers

d. Vapor and evaporator heat exchanger drain feedheaters.

531-2.2.8.3.2 Air vents are installed where air accumulates. Inability to obtain rated capacity in an evaporator is often due solely to accumulated air. A vent or equalizing line usually is provided from each drain regulator to the evaporator heat exchanger it serves.

531-2.2.8.4 Drain Cocks. Drain cock valves are provided at low points in all units so that water can be removed before any unit is opened for cleaning or repairs.

531-2.2.8.5 Water Level in Shells. The water level in basket-type plants and submerged-tube plants with fixed weirs is self-regulating; do not adjust it manually. In other submerged-tube plants maintain a constant water level in the evaporator shells at all times. The ordinary level is at the top of the heat exchanger tubes, but it may be necessary to lower the water levels slightly to prevent priming when the ship rolls. Trying to dry the vapor by heating it with uncovered tube surface is impractical. Scale forms rapidly on exposed tubes, causing a loss of working heating surface. The correct water level depends on the capacity at which the plant is operating, maximum brine density, and the extent to which the ship is rolling and pitching. Regulate the water level by adjusting the feed control valves and the discharge valve of the brine overboard pump or by weir level control. Most evaporators have a round sight glass, located at the normal working feed level in the evaporator shell, for observing the internal operation of the evaporator and the condition (scaling) of the evaporator heat exchanger.

531-2.2.8.6 Feed Rate. Once the evaporators are operating, maintain the feed supply at a steady rate. With submerged-tube plants this rate depends on the capacity at which the evaporator is being operated. Avoid changing the feed rate suddenly or maintaining too high a level, as this may cause priming.

531-2.2.8.7 Air Ejector Condenser Leakoff. If the flow of evaporator feed through the air ejector condenser is temporarily stopped during operation, because of accidental flooding of the first-effect shell or some other cause, vapor may be discharged through the air ejector after-condenser vent pipe. This condition can be remedied by opening the valve in the leakoff line from the air ejector condenser to the distiller condenser overboard discharge line (beyond the back-pressure valve). To prevent the loss of large amounts of heated feed, leave this valve closed unless more circulating water is required for the air ejector condenser. A small amount of steam purging from the vent pipe at higher ambient seawater feed temperature is normal.

531-2.2.8.8 Evaporator Gage Glass. The brine level observed in the outside gage glass of each evaporator is usually lower than the level observed through the sight glass. This is because vapor bubbles, which increase the liquid volume inside the evaporator shell, are absent from the gage glass. This difference is greater when the plant is operated at full capacity than when it is operated at low capacity, and is also greater in the last-effect shell than in the first-effect shell. Mark the evaporator gage glass to show the correct working level, as determined from experience, for various plant capacities.

531-2.2.8.9 Drain Levels. Condensate should be visible in the gage glasses of the automatic drain regulators for each evaporator heat exchanger to maintain a water seal and to prevent steam from blowing through the tube nest without condensing completely. If regulators become inoperative, they may be bypassed or locked open and manual drain valves used. At very low capacities the differential pressure available in some plants may be insufficient to provide for adequate drainage of tube nests, and flooding and erratic operation will occur until the pressure is increased.

531-2.2.8.10 Using Salinometer. The salinometer is an instrument that uses a float to measure the degree of salinity or concentration of brine. It is a hollow, metal vessel weighted with shot at the bottom and has a projecting stem graduated in four scales to read the salinity for various brine temperatures. The graduations are marked in 32nds, from 0 to 5. When the salinity of a sample of brine is to be measured, its temperature should correspond to one of the scales on the instrument so an accurate reading is possible. Check the accuracy of the salinometer occasionally by placing the instrument in pure freshwater (in which it should sink to the zero mark on the scale corresponding to the temperature of the water). Standard salinometer sets are available from stock.

531-2.2.8.10.1 The pot that holds the brine sample must be deep enough for the salinometer not to touch bottom. To use, fill the pot with brine and insert the thermometer. Allow the sample to cool to one of the scale temperatures; then, insert the salinometer and read the degree of salinity. When the salinometer is removed, wipe off all moisture, as accumulations of salt or dirt on the salinometer will affect the accuracy of its readings.

531-2.2.8.10.2 Brine samples for salinity concentration tests are usually obtained from test cocks on the discharge side of the brine pump. Be sure that gland sealing water for the brine pump is shut off before using this test cock, or the brine sample may be diluted by gland sealing water leaking into the brine. This will lead to inaccurate salinity readings. Some older plants furnish salinity test pots, which are connected to the last-effect shell or to the brine pump suction. Since they are connected to the vacuum side, they require double valves, one set to fill the test pot under vacuum, the second to break the vacuum and drain to the salinometer pot. In plants with brine diluting lines connected to the brine pump suction line, shut off the flow of diluting water before withdrawing each brine sample.

531-2.2.8.11 Pumps. Take great care with centrifugal pumps that operate with suction below atmospheric pressure: fittings in the suction line must be tight, and the pump gland sealing water must be sufficient to prevent air from entering the pump through the shaft packing. For information on the care, operation, and repair of all types of pumps, see**NSTM Chapter 503, Pumps.**

531-2.2.8.12 Brine Pump Diluting Line. The correct use of the brine diluting line provided in some distilling plants is to admit cold seawater to the brine flow before it enters the brine pump. This will prevent vapor binding in the pump and minimize scale formation on the pump impeller. The flow through the dilution line must be carefully regulated, however, to ensure that the combined brine plus dilution flow does not exceed the capacity of the brine pump. The optimum setting of the control valve in the brine-diluting line will result in a brine temperature drop of about 20°F.

531-2.2.8.13 Eliminating Leaks. Eliminating air and water leaks is essential to the successful operation of any distilling plant. Air leaks usually reduce plant capacity; water leaks contaminate the distillate.

531-2.2.8.13.1 Periodically test all distilling apparatus so that the system can be maintained leakproof.

531-2.2.8.13.2 During an extended lay-up period (as with ships on the inactive list) internal gaskets may tend to dry out. If water of the desired purity cannot be made after such a lay-up period, inspect the gaskets and renew them as described in paragraphs 531-2.4.11 through 531-2.4.11.2.

531-2.2.8.14 Testing Distillate. Chemically test the accuracy of the electrical salinity-indicator readings frequently, as described in **NSTM Chapter 220, Volume 2, Boiler Water/Feedwater Test and Treatment.**

531-2.2.8.14.1 The relation between grains of sea salt per gallon (as shown by salinity indicators that lack new epm scales) and epm of chloride as determined by chemical titration is discussed in **NSTM Chapter 220, Volume 2.** Use the following approximation for checking: epm chloride x 4.0 = grains of sea salt per gallon.

531-2.2.8.14.2 Experience has shown that if a low-pressure distilling plant cannot make distilled water with chloride content below 0.065 epm (0.25 grain of sea salt per gallon), the plant is not operating satisfactorily. When this occurs locate the cause of the high salinity and eliminate it immediately. See paragraphs 531-2.3.2.3 through 531-2.3.2.3.5 for locating contamination sources.

531-2.2.8.15 Measuring. Some method to continuously measure the output of the evaporators (other than soundings of the ship's reserve feed tank) is essential to correctly operate a distilling plant. Most ships have freshwater meters for measuring the quantity of freshwater the distilling plant produces. To ensure accuracy, calibrate the meters when availability permits. Provide columns in the evaporator log to enter the water produced hourly and the amount of water distilled daily by each evaporator.

531-2.2.8.16 Condition of Heat Exchanger Surface. The capacity and economy of a distilling plant are affected by the cleanliness of the various heat exchanger tube surfaces. The gain in economy and capacity obtained by using the various feedheaters is considerable. Except for the evaporator heat exchangers, the heat-exchanging surfaces should require only infrequent cleaning. The evaporating tubes may require descaling every 6 months or less, depending on operating conditions and whether feed treatment is used. A simultaneous check of feed and drain temperatures will indicate the effectiveness of the various heat exchangers, including the distiller condensers, and will indicate the cleaning requirements.

531-2.2.9 OPERATION IN CONTAMINATED WATERS. When operating a distilling plant in contaminated waters, the health of the crew may be endangered unless the following instructions are rigidly adhered to:

a. Operate the plant at a low distilling rate, with comparatively low water levels in each shell to minimize the possibility of priming or carryover.

b. Transferring evaporator distilled water to the ship's drinking water tanks if the chloride content exceeds 0.065 epm (0.25 grain of sea salt per gallon) is absolutely forbidden. If the method of operation would permit a momentary flow of water containing more than 0.065 epm of chloride (0.25 grain of sea salt per gallon), maintain the temperature of the first-effect shell at no less than 165°F (18 inches of Hg gage).

c. When operating in fresh or brackish contaminated water, maintain the temperature of the first-effect shell at no less than 165°F at all times. In such waters the density of the feed may be so low that a low salinity reading for the distillate will not ensure freedom from priming and carryover (that is, from contamination).

d. When operating submerged-tube or vertical-basket distilling units with brackish feed, the requirements of the preceding paragraph guard against contamination of the distillate from carryover but not from a leaking tube in the distillate cooler or the distiller condenser. The Medical Department representative on the ship should be aware of this possibility.

531-2.2.9.1 Unless it is determined otherwise by suitable tests, consider all water in harbors, rivers, inlets, bays, landlocked-waters, and in the open sea within 12 miles of the entrance to such waters to be contaminated. In other areas, the fleet surgeon or his representative may declare contamination to exist if the local conditions warrant such action.

531-2.2.9.2 Responsibility for determining the purity of potable water rests with the Medical Department representative, who shall be guided by Chapter 6, Water Supply Afloat, of NAVMED P-5010-6, **Manual of Naval Preventive Medication.** This manual contains detailed procedures for inspecting and correcting potable water contamination.

531-2.2.10 STARTUP PROCEDURE. To start a submerged-tube distilling plant with evaporators empty and all pumps shut down, proceed as follows:

1. Open the valves in the first-effect heat exchanger drain lines and the air ejector condenser (to waste) drain lines. Do not return the discharge from these lines to the freshwater drain collecting system until it satisfies the appropriate chemical tests. Close the valves in the tube nest drains of succeeding effects.
2. Open all valves in the circulating water suction and discharge lines, and start the circulating-water pump. Open all air vent valves on the distiller condenser head, and close them as soon as all trapped air is vented. If the distillate cooler is fitted with vents on the seawater side, open these valves until all trapped air is vented.
3. Adjust the valve in the circulating water overboard line to maintain a pressure at the circulating-water outlet connection high enough to feed the evaporator, or the evaporator feed pump when installed.
4. Open all valves in the evaporator feed system except the valve in the air ejector condenser outlet leakoff line. Bypass valves around any heat exchanger units should remain closed. If weir level controls are provided, raise the weir overflow pipes to their highest position.
5. Fill each evaporator shell to the top of the heat exchanger. If an evaporator feed pump is installed, it should be used for this purpose. Open all vent valves at high points in the circulating-water and evaporator feed lines until all trapped air is freed.
6. Close the feed valves to the first effect and between effects to prevent water from siphoning into the last effect as the vacuum is obtained.
7. Open the valve in the emergency overboard line from the feed outlet (at the air ejector condenser). The valve or valves in the vent lines from the first-effect steam chest (or evaporator head) must be tightly closed. The steam chest vent lines on succeeding effects should be wide open.
8. Open the gland sealing line to the brine pump.
9. Start the air ejector, first making sure that the air vent from the shell of the air ejector condenser to the atmosphere is free of obstruction. Open the gate valve(s) in the air suction and discharge lines to the air ejector, if installed. (Double or twin air ejectors are usually installed, although one unit is enough under usual conditions.) Admit motive steam to the air ejector nozzle, opening the steam valve wide. Make sure that the steam line to the air ejector nozzle is properly drained. For satisfactory operation the pressure at the nozzle must be at least that specified on the air ejector name plate and the steam must be dry. The air valve to the idle air ejector unit should be tightly closed.
10. Check the salinity of the air ejector condenser drains. When tests indicate that the chloride content is lower than 0.065 epm (0.25 grain of sea salt per gallon), direct the drains into the drain collection system. (In submarines dump this condensate to the bilge.)

11. A full vacuum of at least 26 inches Hg should now exist in all evaporator shells. Failure to obtain this vacuum indicates possible air leaks or air ejector problems.

12. When assured of a tight system, open the first-effect steam supply valve and adjust the regulating valve to provide the required pressure above the orifice plate.

13. If a first-effect heat exchanger drain pump is installed, proceed as follows:

    a. Unlock the drain valve mechanism to permit float operation, or close the bypass around the drain regulator.

    b. When a condensate level appears in the drain regulator gage glass, open the valve (if installed) in the drain pump suction line and start the pump, making sure that the pump vent and gland sealing lines are open. If the drains to the bilge are connected ahead of the drain regulator, a water level may not appear in the regulator gage glass unless the valve in the bilge line is hand-regulated to obtain and hold a water level. If the water level continues to rise to the top of the regulator gage glass, check for air leakage, especially at the pump glands. Check the salinity of the tube nest drain discharge. When tests indicate that it is pure, direct the discharge to the drain collection system.

    c. Open (about one turn) the valve or valves venting the tube nest to the first-effect shell. (In some installations these valves vent to the last-effect shell).

14. If the first-effect tube nest drains discharge to a main or auxiliary condenser without the aid of a tube nest drain pump, proceed as follows:

    a. Open the drain regulator bypass, or lock the regulator wide open with the mechanism provided.

    b. Check the salinity of the drain discharge. When tests indicate purity, close the valve draining to the bilge. Open the valve discharging to the condenser, and close the regulator bypass valve or unlock the drainer valve mechanism. When a water level appears in the drain regulator gage glass, open the valve or valves venting the tube nest to the first-or last-effect shell about one turn. The drain regulator will automatically maintain a water level and seal the tube nest from the condenser to which it is discharging.

15. When a condensate level appears in the drain regulator gages on the succeeding effects, open the discharge valve from each regulator so that the distilled water drains will be carried to the flash chamber, if installed.

16. When condensate appears in the last-effect flash chamber, start the distillate pump and open all valves in the discharge line from this pump to the solenoid-operated bypass valve. Make sure the solenoid-operated bypass valve is set to discharge to waste. Be sure the distillate pump vent and sealing water line valves are open.

17. Lower the weir overflow pipes, if provided, to their operating positions.

18. When vapor begins to pass into the distiller condenser, check the relative temperatures of circulating water in and out of the distiller condenser. Maintain this difference within 20°F. If the difference in temperature is greater when the plant is brought up to capacity, adjust the overboard discharge valve to increase the flow of cooling water.

19. Open all valves in the brine overboard line except the brine pump discharge valve. Open the valve in the vent line between the brine pump suction and the last-effect shell (or the distiller condenser shell). Start the brine pump, and open the bypass valve (around the pump discharge valve) about 1-1/2 turns, or the amount previously determined to be necessary for normal operation. The brine overboard valve at the sea chest or at the connection to the circulating-water overboard line should always be wide open during plant operation.

20. As the output of the plant increases, water levels in all shells will drop. Adjust the feed valves or weir level controls to each shell to the desired position; that is, to maintain the boiling water level just even with the top of the tubes. Adjust all valves in the steam chest vent lines to their normal operating position (about one turn open). The valve in the emergency overboard line from the feed outlet of the air ejector condenser should be closed, and opened only when steam is evident at the air ejector condenser vents.

21. Check the density of the brine pump discharge with the salinometer, and adjust the control valve until the density is 1.5/32.

22. After steady levels have been reached in each evaporator shell, and the last-effect brine density is constant at 1.5/32, check the quality of the distilled water. First, make sure that the salinity-indicator electrical system is energized. The meter pointer should indicate zero on the scale with the selector switch in the OFF position. Select the particular salinity cell location where a measurement is desired, and turn the selector switch to the number of that cell (given in the table of cell locations). The meter should indicate the salt content directly in epm of chloride or grains of sea salt per gallon.

CAUTION

Do not lock the solenoid-operated bypass valve open during plant operation, as this may allow contamination of the potable water supply.

23. When the distillate purity is satisfactory, that is, chloride content does not exceed 0.065 epm (or 0.25 grain of sea salt per gallon), set the solenoid valve to discharge to the freshwater system, and open the meter valves. When in this position, the valve will trip automatically to discharge impure water to waste.

531-2.2.11 SECURING PROCEDURE. The procedure for shutting down a low-pressure distilling plant is as follows:

1. Notify the officer of the watch that the distilling plant is ready to be shut down and request that auxiliary exhaust and air ejector steam supply lines, and first-effect evaporator tube nest and air-ejector condenser drain lines be closed in the engine room.
2. Close the valve in the first-effect tube nest steam supply line.
3. Shut off the steam supply to the air ejector, and close the air suction valve between the distiller condenser and the air ejector.
4. Shut off the first-effect tube nest drain pump (when provided), and shut the valves in all drain lines from the first-effect tube nest and air ejector condenser.
5. Shut off the distillate pump and the suction and discharge valves at the pump.
6. Close all valves around the water meter.
7. Open wide all valves in the steam chest vent lines to equalize pressure in all units.
8. Allow the circulating pump, evaporator feed pump (when supplied), and brine overboard pump to continue operating for 15 minutes to cool the distilling plant.
9. Fill each evaporator shell until the water level is just above the top row of evaporator tubes, and shut down the brine pump, circulating pump, and evaporator feed pump (when supplied). High levels in the shells can flood the vent lines, distiller condenser, and air ejector condenser with salt water.
10. Close the suction and discharge valves for all pumps except the adjusting valve for the brine overboard density control.
11. Close all suction and overboard sea chest valves. Also close the valve (if supplied) in the brine line that discharges into the circulating-water overboard line.
12. Close the feed valves to each evaporator shell.
13. Open the drain lines to the bilge from the first-effect tube nest and air ejector condenser.

14. Close the inlet and outlet valves to the drain regulators, and close all the valves in the vent lines into the shells from tube nests and from distillate, brine, and tube nest drain pumps.

531-2.3 OPERATING TROUBLES AND CORRECTIONS

531-2.3.1 REDUCTION IN CAPACITY. The following faults will reduce capacity:

a. Air leaks
b. Cold seawater feed
c. Scale deposit on tubes
d. Irregular or improper feeding
e. Improper drainage of tube nests.

531-2.3.1.1 Air Leaks. The importance of eliminating air leaks cannot be stressed enough. Most troubles with distilling plants are directly due to air leaks. Take great care in making up joints and keeping them tight. Test all joints under pressure and shellac them frequently. Leaks commonly occur in the glands of the tube nest drain, brine-overboard and distillate pumps (including the casing and suction joints), and gage-glass fittings. Install a gage-glass fitting that allows the packing to be set up without putting any torsional strain on the glass.

531-2.3.1.2 Cold Seawater Feed. Check the feed temperatures frequently to ensure that the correct rise in temperature is obtained through the various heaters. Keep the distiller overboard discharge temperature as high as possible by throttling the overboard discharge valve while still maintaining the proper vacuum in the distillers.

531-2.3.1.3 Scale. With correct seawater feed distribution, the density of last-effect brine maintained at 1.5/32, and steam pressure above the orifice not over 5 pounds, very little scale should form when using seawater for feeding evaporators.

531-2.3.1.3.1 In many areas large amounts of vegetable matter and fuel oil may cause difficulties in operating distilling plants by coating the evaporator and heat exchanger tube surfaces with an organic deposit that is difficult to remove. Under these conditions it may seem preferable to use shore water as feed to the distilling plants. Operate distilling plants with shore water feed as rarely as possible. Shore water may contain large amounts of scale-forming salts like carbonates, sulfates, and silicates. Using shore water as evaporator feed may cause a tough, adherent scale to form that can be more difficult to remove from evaporator tubes than fuel oil. Before entering areas where fouling of evaporators is possible, completely fill the freshwater tanks to avoid the need to use the distilling plants. When a long stay in such localities necessitates the use of shore water for evaporator feed, treat the feed. Scale on the tubes of the other distilling plant heat exchangers, such as the vapor feedheaters and the air ejector condensers, is more difficult to remove after such operation.

531-2.3.1.3.2 Inspect for scale on tubes frequently until the correct interval for scaling is ascertained. Clean sump tanks and strainers frequently. Inspect saltwater and brine piping, valves, separators, feedheaters, and the inside of pumps frequently for scale, and clean them out when necessary.

531-2.3.1.4 Irregular or Incorrect Feeding. In submerged-tube distilling plants the capacity of the plant and the purity of the freshwater produced are sensitive to variations in feed level. For a given operating condition, maintain a constant feed level in all effects. Failure to feed correctly may be caused by clogged strainers or by insufficient pressure on the distiller circulating overboard discharge line. Correct the latter by throttling the overboard discharge or by increasing the pressure setting of the spring-l oaded regulating valve.

531-2.3.1.5 Faulty Drainage of Evaporator Heat Exchangers. Drain regulators are installed to prevent steam and vapor from blowing through the heat exchangers before they can be condensed and give up their latent heat. Faulty operation may either stop the drains or allow steam and vapor to blow through. The drain stoppage in the first effect results in condensate backing up and reducing the heating surface. In the second and third effects the result is the same. In addition, since the drains make up a part of the distilled water output, the capacity is reduced directly as well as by the loss of effective heating surface. Since these regulators all operate under vacuum, take great care that all joints are free of air leaks. To ensure proper operation of the float, open the equalizing and vent connections.

531-2.3.2 HIGH SALINITY. High salinity of the distillate can be caused by leakage of saltwater into the vapor or freshwater circuits, or by priming, as described below.

531-2.3.2.1 Leakage. The tubes or tube joints of the distiller condenser, vapor feedheaters, and distillate cooler may leak. Test individual units for leakage by manipulating the bypass valves around the units and reading of the appropriate salinity cells as described in paragraph 531-2.3.2.3.

531-2.3.2.2 Priming. Priming, the carryover (in the vapor) of small quantities of brine, is caused by the following:

a. Excessive generating steam pressure with clean heating tubes, giving overload capacity

b. Vacuum too high in distiller condenser

c. Fluctuating generating steam pressure and temperature

d. Feed level in shells not carried at proper points (submerged- tube plant)

e. Unsteady feed (submerged-tube plant)

f. Unsteady brine discharge (submerged-tube plant)

g. Salinity of brine in last effect too high

h. Faulty venting or draining of tube nests

i. Malfunctioning of vapor separators due to clogging or gaps in wire mesh demisters.

531-2.3.2.3 Determining Causes of High Salinity. Use the salinity-indicating system described in paragraph 531-2.1.6 to find the location and cause of contamination by measuring the salinity at various points in the system. During normal plant operation the selector switch of the salinity-indicating system should be set to indicate the purity of the distillate pump discharge, which is the combined output of all the evaporator units of the distilling plant. If high salinity is indicated, turn the selector switch successively to indicate the salinity at the various points in the system where cells are located, taking care in all cases to make proper adjustments for temperature.

531-2.3.2.3.1 If the salinity cell in the distiller condenser drain line (ahead of the flash chamber) indicates high salinity, possible sources are carryover from the last-effect evaporator shell or a leaky tube in the distiller condenser.

531-2.3.2.3.2 If the cell in the last-effect heat exchanger drain line indicates high salinity, the possible sources are carryover from the first-effect or second-effect shell, or a leaky tube in the first-effect or second-effect vapor feedheater.

531-2.3.2.3.3 If the salinity cell in the heat exchanger drain line from the second-effect evaporator of a triple-effect plant indicates high salinity, the possible sources are a leaky tube in the first-effect vapor feedheater or carryover from the first-effect evaporator shell. As mentioned above, unsteady operating conditions - variations in generating steam pressure or temperature, in last-effect vacuum, and in the rate of feeding - also have pronounced effects on the purity of the freshwater the plant produces. Any or all the above cells may show high readings during unsteady plant operation. Leaky tubes in various heaters and coolers may be detected by bypassing the units, if bypasses are installed. If contamination disappears when a unit is bypassed, a leaky tube in this unit is indicated. Leaking feedheaters can be bypassed without permanent damage until it is convenient to repair them. Since the economy of the plant is adversely affected, however, return them to use as soon as possible.

531-2.3.2.3.4 If high salinity is indicated by the cell in the first-effect tube nest drain when the plant is shut down, a tube leak in the first-effect evaporator heat exchanger is indicated. Similarly, high salinity indicated by the cell located in the second-effect or third-effect tube nest drain when the plant is shut down would indicate a tube leak in the second-effect or third-effect tube nest drain, respectively. Such a leak would not show up during operation because of the lower pressure in the shell (than in the tube bundle). In plants supplied with tube nest drain feedheaters, a high reading from this cell would indicate a leak in the heater.

531-2.3.2.3.5 A leaky tube in the air ejector condenser is indicated by a high reading on the salinity cell in the drain line from this unit. A leaky tube in the distillate cooler is indicated by a high reading on the salinity cell in the distillate cooler drain line if the other cells upstream do not show high readings.

531-2.3.3 AIR EJECTORS In operation air ejectors require very little attention, but note the following:

a. The steam pressure at the nozzle inlet shall be no less than that for which the ejector is designed and that is stamped on the name plate. The pressure drop in the steam line may be substantial, and if the steam pressure is not measured at the inlet nozzle, it may be necessary to carry a higher pressure on the gage. Pressures at the air ejector nozzle of 10 to 15 psi above that specified as the minimum are acceptable.

b. The primary causes of air ejector trouble are low steam pressure, wet steam, obstructed nozzles or clogged steam strainers. Such trouble is indicated by failure to obtain or to maintain a vacuum, or by fluctuation of the vacuum. If the trouble is due to low steam pressure or to wet steam, it is essential to increase the steam pressure or to use suitable drainage, either manual or through a trap. If the nozzle or steam strainer is clogged, remove and clean it.

c. Some plants have two air ejectors, although only one is required for normal operation. This allows the plant to operate on one unit while the second ejector is dismantled for cleaning or repair. The latest plants have only one air ejector. The second ejector is sometimes used during initial startup for fast evacuation. To shift from the ejector unit in operation to the spare unit, proceed as follows:
    1. Open the steam valve to the nozzle of the spare unit.
    2. Open the air suction valve to the spare unit.
    3. Close the air suction valve to the originally operating unit.
    4. Close the steam valve to the nozzle of the originally operating unit.

531-2.4 MAINTENANCE

531-2.4.1 GENERAL. Full output can be maintained without interruption for long periods only if every part of the plant is maintained in operating condition. This can be ensured by periodic inspections and tests, cleaning or replacing parts as necessary. The maintenance suggested below can be modified slightly as experience with a particular installation indicates.

531-2.4.2 STRAINERS. Quick-opening, flanged, basket-type strainers are required in the brine and circulating pump suction lines for correct operation of the distilling plant.

531-2.4.2.1 Brine Pump Strainers. Inspect the brine pump suction strainers on submerged-tube plants daily and install a clean basket when necessary. A clogging strainer will interfere with the operation of the pump and will make it impossible to hold the brine density to less than 1.5/32.

531-2.4.2.2 Circulating Pump Strainers. Inspect the circulating pump suction strainer about once a week when at sea and once every 24 hours when in port. Even partial clogging of this strainer will reduce the flow of circulating water and, consequently, reduce the vacuum. This, in turn, may cause scale to form more rapidly on evaporator heat exchanger surfaces and inside vapor feed-heater and air ejector condenser tubes.

531-2.4.3 AIR EJECTORS. The air ejector steam strainer is usually an integral part of the air ejector inlet. Inspect it regularly and clean it whenever necessary. When a new plant is first operated, the strainer may require frequent cleaning until the lines have been thoroughly cleaned out. Failure to keep the strainer clean will cause a reduced and fluctuating vacuum. If a strainer is damaged, replace it with a new one. Spare strainer baskets are provided with each plant.

531-2.4.3.1 Clogging or scoring of the air ejector nozzle will cause the same faulty operation as clogging of the strainer. Clean the nozzle with a nozzle reamer provided for this purpose or with a wooden stick or piece of soft wire. Never use a file or other sharp instrument for cleaning; it may score and ruin the nozzle. The nozzle may be removed for cleaning and inspection, but cleaning alone can be accomplished with the nozzle in place. If the nozzle is scored replace it with a new one. At least one spare nozzle is supplied to each ship.

531-2.4.4 SALINOMETERS. Test the salinometers at monthly intervals by measuring the density of distilled water. A sample at the correct temperature can be obtained by temporarily bypassing the distillate cooler, or heat the sample. If distilled water is at the correct temperature the instrument should read zero. Always keep at least one extra salinometer on hand.

531-2.4.5 ZINCS. Zinc rods or zinc plates are provided in most saltwater units (except in the evaporator shell) to reduce the effects of galvanic action on structural parts. Inspect and clean the zincs regularly (once every 90 days or in accordance with Planned Maintenance System (PMS) instructions). When more than half the zinc has corroded away, install a new zinc. Refer to appropriate plans for the location of zinc pencils or plates. Zincs at the return head of vapor feedheaters (when these are within the evaporator shells) can be inspected only when the vapor feedheater bundles are withdrawn. This is also the case with zincs at the return head of distiller condensers on Soloshell end-pull distilling plants. Replace these relatively inaccessible zincs only when the plant is dismantled for descaling.

531-2.4.6 HYDROSTATIC TESTS. Conduct a shell-side hydrostatic test of 8 to 10 psi when there is indication that air leakage is the possible cause of operating difficulty. Conduct a hydrostatic test after reassembly also when the plant has been dismantled for cleaning. Refer to Appendix B for a hydrostatic test procedure.

531-2.4.7 PUMPS AND PUMP PIPING. Proper operation of all pumps is essential for successful operation of low-pressure distilling plants. Pump problems such as those in the following list can cause excessive scale formation and reduce output:

a. Check the speed and rotational direction of each pump when first starting a new plant and after electrical work has been done.

b. All pump piping must be airtight. Even the slightest air leakage, particularly on the suction side of the tube-nest drain, distillate, and brine pumps, will result in improper operation. In looking for air leaks, do not overlook gage and vent lines. Hydrostatic tests of the distilling plant should include pump piping.

c. Only if gages indicate a possible problem should the pump be completely dismantled, wearing ring clearances checked, and the pump completely repacked. Adding additional rings of packing indefinitely is unacceptable. It gradually displaces the lantern ring until it is no longer directly below the external water seal connection. For additional information on packing, refer to **NSTM Chapter 503.**

531-2.4.8 DETECTING TUBE LEAKAGE. A method for detecting the presence of tube leaks is outlined in paragraphs 531-2.3.2.3 through 531-2.3.2.3.3. To determine which of the tubes within a bundle is leaking, hydrostatically test the individual bundles according to the following instructions:

a. If the leak is in a removable bundle (vapor feedheaters when within an evaporator shell, evaporator tube nests, distiller condensers on Soloshell end-pull plants), withdraw the bundle and apply a hydrostatic test at full pressure (50 psig) on the tube side.

b. If a leak occurs in a nonremovable bundle (condensate coolers, air ejector condenser, external vapor feedheaters), remove the tube nest and apply the full test pressure of 50 psi on the shell side of the unit.

c. When a nonremovable distiller condenser bundle is in an evaporator shell, remove the tube nest covers and apply the full test pressure of 30 psi to the evaporator shell.

d. If the distiller condenser is fitted with a diaphragm-type (Goubert) expansion joint, a test ring will be required to replace the tube nest cover for testing.

531-2.4.9 TUBE EXPANDING. All tubes in low-pressure distilling plants are expanded into tube sheets at both ends. Allowance is made for differential expansion either by the use of floating heads or by expansion joints on the shell side. Leaky tube joints may be repaired by re-expanding them. The evaporator tubes are 5/8-inch OD, 16-gage Admiralty Metal (TM) and all other tubes are 5/8-inch OD, 18-gage copper nickel alloy. Tube expanders for both sizes are provided with the distilling plants. Expand the tubes according to the following procedure:

1. Set the adjusting nut, and check the nut so that the forward end of the rollers extends out from the adjusting nut stop collar a distance approximately 1/8-inch less than the thickness of the tube sheet. Insert the expander in the tube to be expanded until the adjusting nut stop collar is in contact with the tube sheet. While holding the cage firmly in this position with one hand, push the mandrel forward until it is in firm contact with the rollers.

2. Expand the tube by rotating the mandrel clockwise. Turn the expander counterclockwise to withdraw it from the tube. Now, repeat the process, if necessary.

3. Do not overexpand a tube; it may damage the inside of the tube.
4. Wash the expander thoroughly and dip it in lubricating oil frequently to prevent dirt and scale from interfering with the free movement of the rollers within the cage.
5. When only a few tubes are to be rolled, drive the expander by hand. When many tubes are involved, as when retubing an entire unit, drive it with a torque-controlled slow-speed, reversible motor.

531-2.4.10 RETUBING. Correct individual tube leaks by plugging both ends of the tube with tapered phenolic plugs in accordance with MIL-P-15742, **Plastic (Heat-Exchanger-Tube) Plugs.** Plug NSN's are provided in **NSTM Chapter 254, Condensers, Heat Exchangers, and Air Ejectors.** Plugging too many tubes, however, will reduce the amount of heating surface, and in some multipass heat exchanger units may cause excessive tube velocities. When retubing becomes necessary, refer to**NSTM Chapter 254** for tube removal procedures. After tube removal, retube according to the following procedure:

1. After the tubes have been removed, carefully inspect the tube sheet holes and remove all foreign matter. If necessary, use a reamer of slightly larger diameter to refinish or remove imperfections in the tube hole.
2. Thoroughly clean the ends of the new tubes. They should extend out about 1/16 inch from the tube sheets at both ends. Place a drop or two of lubricating oil inside each tube to help lubricate the expander rolls.
3. Lightly drift one end of each tube in place to keep the tube from rolling with the expander. Follow the tube expanding procedure outlined in paragraph 531-2.4.9.
4. Complete the total rolling operation by first expanding a few tubes around the outer periphery and a few near the center of the tube sheet. Then, work from the center outward until all tubes are expanded.
5. After rolling, flare the tubes into the flare machined into the tube sheet. Tubes may be flared at both ends, and shall be flared at the inlet end. A flaring tool is furnished with each plant. To use it, drive the tool into the tube until the tube is opened at the end and fits snugly into the flare in the tube sheet.
6. Machine or grind the expanded and flared tubes flush with the surface of the tube sheet. Use a disk sander, grinder, or a cup-grinding wheel for this purpose.
7. Copper nickel alloy tubes (18-gage) may be substituted for Admiralty Metal evaporator tubes, but not the other way around.

531-2.4.11 GASKET REPAIR. Failure of the gasket between the shell flange and tube sheet in fixed bundle heat exchangers rarely causes leaks if the shoulder bolts usually provided in these exchangers are used correctly. Replacing these gaskets involves costly retubing of the complete exchanger. Should such a joint leak, a repair that will usually avoid the necessity for retubing can be made by applying the following procedure:

1. Cut a circumferential groove in the bolts that secure the shell flange-tube sheet joint. This groove should be 1/8 inch deep and should span the joint to be sealed.
2. Drill a 1/8 inch hole longitudinally through the head and body of the bolt to intersect a transverse hole drilled from the groove.
3. Tap the hole in the bolt head for a pressure-type grease fitting.
4. Loosen the joint slightly. Inject a nondrying gasket-forming compound (such as Permatex number 3 or equal) through the pressure fitting. Do not use a gasket-forming compound that contains lead.
5. Tighten the joint.

531-2.4.11.1 When the preceding method is unsuccessful and replacement of the original gaskets is necessary, use acid-resistant rubber conforming to MIL-R-21252, **Shipboard Water Evaporator Gasketing Solid Rubber Sheet -** NSN 9Z5330-00-850-3501 for 1/16-inch-thick gaskets and NSN 9Z5330-00-850-3502 for 1/8-inch-thick gaskets.

531-2.4.11.2 Use no material containing asbestos for gaskets. Use no gasket-sealing compounds that contain lead. Obtain approved sealing compounds under the following NSN's:

a. 8040-00-144-9774 (12-ounce cartridge)

b. 8040-00-118-2695 (3-ounce tube).

531-2.5 CLEANING

531-2.5.1 SCALE BUILDUP. During the operation of a seawater distilling unit, scale forms on the heating surfaces of the evaporator and, to some extent, in the tubes of the heat exchangers. The rate of buildup and the composition of the deposits depend on such factors as temperature, whether seawater or shore water is used for feed, the density of the brine, and the rate of flow. Appropriate feed treatment will also help to slow the rate of scale formation.

531-2.5.2 TYPES OF CLEANING. Two types of cleaning (chemical and mechanical) are available. Chemical cleaning is the preferred type because it is faster, more economical, more effective, and less harmful to evaporator parts than mechanical cleaning. Chemical cleaning involves circulating heated, dilute acid solution through the saltwater (feed and brine) circuits of the system by means of the brine overboard pump or a special acid-resistant pump. Dismantling the unit for chemical cleaning is unnecessary.

531-2.5.3 GENERAL INSTRUCTIONS. The following instructions apply to all low-pressure steam distilling plants.

531-2.5.3.1 When to Clean. Clean submerged-tube type evaporators when the first-effect tube bundle vacuum falls below 3 inches of Hg or when the distillation capacity is inadequate. With proper operation the interval between cleanings should be 6 months or more. If the Navy standard scale preventive compound as described in paragraph 531-2.2.7 is used as a feed treatment, the interval between cleanings will be significantly increased. Avoid operating at positive pressure in the first-effect tube bundle except in cases of emergency, because this will increase the production of calcium sulfate scale, which is difficult to remove.

531-2.5.3.1.1 Clean vertical-basket evaporators when it is necessary to use a steam pressure of 4 to 5 psig in the first effect to produce rated capacity. (Do not let first-effect steam pressure exceed 5 psig.) If cleaning is required, examining the first-effect basket through the observation glasses or the quick-opening door will reveal heavy scaling.

531-2.5.3.1.2 If a convenient availability occurs after a long period of operation that would normally require descaling, cleaning the evaporators may be desirable even though the decrease in output or increase in steam pressure is not yet critical. This is particularly true if heavy deposits can be seen on the heating surfaces and if a long period of operation is scheduled before the next availability.

531-2.5.3.2 Miscellaneous Cleaning. Whenever the distilling plant is dismantled, a number of interior parts should be inspected and, if necessary, cleaned.

531-2.5.3.2.1 Remove the feed distributing pipes, flushing pipes, and separator drain lines, and clean off any scale deposits. The hooks on the lower baffles, the troughs formed by these baffles, and the shell are drained by gaps or slots at the ends. Remove scale deposits at these points to ensure proper drainage. Inspect the upper and lower gage glass equalizer lines, the gage glass fittings, gage glasses, sight glasses, feed lines between effects, brine lines, brine pump impeller, and so forth, and clean if necessary.

531-2.5.3.2.2 If this work is done at a naval shipyard, any part that can be removed from the ship may be cleaned in the shop by dipping in a sulfamic acid solution followed by thorough flushing (provided that such acid cleaning is accomplished under the supervision of competent yard personnel). The scale must otherwise be removed mechanically.

531-2.5.3.3 Cleaning Interiors of Heat Exchanger Tube. Saltwater flows inside the tubes of the distiller condenser, air ejector condenser, vapor feedheaters, and in recent installations, distillate coolers. Under some operating conditions, scale deposits may accumulate inside these tubes, particularly in the air ejector condenser and first-effect feedheater. Every 6 months or whenever the plant is secured for descaling evaporator tubes, inspect the inside surfaces of these heat exchanger tubes and clean if necessary. Neglect can lead to thick scale deposits which will be difficult to remove.

531-2.5.4 MECHANICAL CLEANING OF EVAPORATORS. When acid cleaning does not satisfactorily clean evaporators or cannot be accomplished, submerged-tube distilling units having square-pitched heat exchangers and basket-type units should be mechanically cleaned according to the following instructions.

531-2.5.4.1 Withdraw the evaporator bundle for cleaning. Lifting gear suitable for the particular installation is usually provided to facilitate the removal of the tube bundles. In some cases, there are overhead trolleys from which the bundles may be suspended. In other cases, roller brackets that can be bolted to the front head are provided along with tracks. For small bundles, special external lifting gear is sometimes omitted since the bundles can be handled easily with an ordinary chain fall or by several persons.

531-2.5.4.2 When the bundle has been withdrawn beyond the support plate, bolt the tube nest stop in place to prevent accidental dropping of the rear head. Remove the tube nest stop when the rear head has been supported by personnel or lifting gear. Withdraw the bundle and lay it on the deck or on a suitable platform. Turn the bundle on its side to permit cleaning both the bottom and the top of the tubes.

531-2.5.4.3 The cleaning tool is operated by a light air hammer. Hold the air hammer against the tube with moderate pressure, and move over the entire length of the tube. Clean every tube in the bundle. Never use a torch for descaling any tube nest made up of straight tubes.

531-2.5.4.4 After cleaning, apply a hydrostatic test of 50 psi to the bundle before replacing it in the shell.

531-2.5.4.5 To mechanically clean basket-type distilling plants, follow special instructions in the technical manual. If feed treatment is used and the plant is operated with brine densities less than 1.5/32, scale accumulation on the basket heat exchanger surfaces should be light. Heavy scale, however, will accumulate on the evaporator shell. This scale can be mechanically removed by careful use of a blunt hammer. Take care not to nick the metal surfaces, as these nicks will cause increased adherence of future scale deposits. Chill-shocking is no longer an approved method of scale removal because of the risk of damage to the basket by high thermal stresses.

531-2.5.5 CHEMICAL CLEANING OF EVAPORATORS. Appendix C and Appendix D contain approved procedures for citric acid (on-line) and sulfamic acid cleaning of evaporators. The methods described permit cleaning the plants by circulating dilute acid solution through the system without dismantling the units. This method of cleaning is to be used whenever possible and is preferred to dismantling the units for mechanical descaling or acid dipping. Cleaning with acid, when accomplished according to instructions, will cause a slight but acceptable dissolution of metal parts and will also have some slight effect on gasket materials. This low-level acid attack should not reduce evaporator life significantly, provided that chemical cleaning is used only when necessary and in the recommended manner. To minimize dissolution of metal parts, use only acids specified in the procedure of Appendix C and Appendix D.

531-2.5.5.1 General. Citric acid is the preferred chemical cleaning method for submerged-tube and basket-type distillers. It is less detrimental to tubes and gaskets, can be performed by the ship's force, and does not require plant shutdown. On-line citric acid cleaning, however, does have the following limitations:

a. It is not approved for use in port, since the brine discharged overboard during citric acid cleaning exceeds environmental regulations.

b. It will not remove heavy scale. If the cleaning schedules shown in paragraphs 531-2.5.3.1 and 531-2.5.3.1.1 result in scale accumulations too heavy to be removed by citric acid cleaning, the ship's force should determine a new first-effect vacuum/pressure (or time interval) for initiation of cleaning.

c. If citric acid cleaning is ineffective, sulfamic acid or mechanical cleaning should be performed.

531-2.5.5.2 Alternative Cleaning. The greatest danger in general adoption of chemical cleaning is that it may be seen as a cure for all evaporator problems and a substitute for all other types of evaporator care. Do not neglect evaporator feed treatment and proper operating procedures with the expectation of removing heavy evaporator scale with chemical cleaning.

531-2.5.5.3 Citric Acid. Citric acid comes in powder form and is safe for storage aboard ship in dry, ventilated spaces. The dry and liquid forms of citric acid can be irritating to the skin, eyes, and nasal passages, so adequate safety precautions shall be observed. Since this procedure does not require chemical testing during the cleaning operation and the chemicals and byproducts involved are relatively safe, citric acid cleaning is authorized for use by shipboard personnel.

531-2.5.5.4 Sulfamic Acid. Sulfamic acid comes in powder form and is safe for storage aboard ship when stored in the containers in which it was shipped. Sulfamic acid, when dissolved in water, presents certain hazards that require care in its handling. The reaction of sulfamic acid with certain metals and with the seawater scale in the distilling unit produces gases that are dangerous in confined spaces. Because this acid does not require chemical testing during the cleaning operation, its use is authorized under the supervision of qualified tender or shipyard personnel. At the discretion of type commanders, individual ships may be authorized to carry this reagent and the cleaning may be performed by qualified personnel in the ship's crew. It is expected that such use will be limited to those ships assigned to extended or detached service during which tender or shipyard availability will be impractical.

531-2.5.5.5 Precautions. Observe certain precautions in the application of the procedures described in Appendix C and Appendix D. Chemical cleaning should be:

a. Used as a supplement to, not a substitute for, feed treatment and proper operating practices

b. Performed under the supervision of qualified shipyard or tender personnel, or by ship's personnel when authorized by the type commander.

531-2.6 HEAT-RECOVERY PLANTS

531-2.6.1 GENERAL DESCRIPTION. Heat-recovery units consist of a single-effect distilling plant with a submerged-tube-type heat exchanger. This heat exchanger uses heat energy contained in the jacket cooling water circulated through diesel main propulsion engines and ship service diesel generators. This unit requires no steam for air ejectors since feed is used as the motive power to operate eductors for air and brine removal.

531-2.6.2 CIRCULATING SYSTEMS. The circulating systems for heat recovery units are:

a. Heat supply circuit

b. Vapor circuit

c. Distilled water circuit

d. Feed circuit

e. Air removal circuit

f. Brine circuit.

531-2.6.2.1 Heat Supply Circuit. Heat is furnished to a heat recovery submerged-tube heat exchanger by the engine jacket cooling water from the propulsion engines and diesel generators. To supplement the heat in the jacket cooling water when engines are running at low rates, units have electric heating modules and steam heaters. This ensures that the jacket cooling water will be at the required temperature when it enters the submerged-tube heat exchanger. The jacket water passes through all heat exchangers (whether energized or not) to the inlet of the submerged-tube bundle where the heat is transferred through the tubes to the feed in the boiling compartment. The jacket water then exits the tube bundle and returns to the engine. This system is fitted with a circulating pump and expansion tank.

531-2.6.2.2 Single-Loop Heat Recovery. Most heat-recovery distillers aboard Navy ships have a secondary heat exchanger between the engine jacket cooling water system and the distiller unit. This heat exchanger isolates the engine coolant, with all its chemical additives, from the distiller. Systems not having this secondary heat exchanger capture heat directly from the engine coolant to support the distiller. This is called a single-loop system. Continuous monitoring of the distillate is required on a single-loop system to ensure that no engine coolant leaks through the distiller submerged-tube heat exchanger. For guidance on monitoring requirements see **NSTM Chapter 233, Diesel Engines.**

531-2.6.2.3 Vapor Circuit. As boiling occurs around the tube bundle, vapor is released and flows upward through the vapor separators or demisters to the distiller condenser.

531-2.6.2.4 Distilled Water Circuit. After the vapor condenses in the relatively cool distiller condenser tubes, it is collected in the distillate trough. The distillate pump draws distillate from the trough and discharges it through the distillate cooler, heating the incoming feed. This system is protected by a salinity-monitoring device that trips a three-way valve to waste if the distillate does not meet purity requirements.

531-2.6.2.5 Feed Circuit. Saltwater is pumped to the evaporator. Part of the feed is used as motive power for the air and brine eductors. The remaining feed circulates through the distillate cooler and distiller condenser and then enters the boiling chamber of the unit. On some units the total seawater flow goes through the distiller condenser. Most then goes to the two eductors, and the rest becomes the evaporator feed. A manually operated valve and flowmeter are installed in the feed line to properly set flow rate.

531-2.6.2.6 Air Removal Circuit. Air is removed by a feed-pressure-motivated eductor that eliminates noncondensable gases from the distiller condenser section of the unit.

531-2.6.2.7 Brine Circuit. On some plants the brine level is controlled by an adjustable brine weir. Excess brine goes to the brine eductor that discharges overboard. The brine eductor uses feed pressure for motive power.

531-2.6.3 CLEANING.

531-2.6.3.1 General Instructions. For cleaning heat-recovery plants, follow the applicable instructions in paragraphs 531-2.5 through 531-2.5.5.5.

531-2.6.3.2 When to Clean. Clean heat-recovery plants when the following symptoms occur:

a. The distillate outlet temperature from the distillate cooler cannot be maintained at less than 95°F when the seawater feed temperature is no greater than 85°F.

b. The condenser cannot maintain the evaporator shell temperature at or below 130°F.

c. The desired distillate production cannot be maintained with full feed flow and maximum heat applied.

SECTION 3.

FLASH-TYPE PLANTS

531-3.1 DESCRIPTION

531-3.1.1 GENERAL. The flash-type distilling plant is widely used throughout the Navy. Flash-type plants are fundamentally different from submerged-tube-type plants. The most important difference is that the feed is flashed into vapor (steam) by pressure reduction, rather than boiling inside the evaporator shell. Vapor is also produced by pressure reduction in each successive stage that the feed/brine enters. Two- through six-stage flash-type distilling plants are used in Navy surface ships. A typical two-stage flash-type distilling plant is shown in Figure 531-3-1. To achieve greater distillate output capacities at a reasonable economy, multiple-stage units are used. These plants use the same principles as two-stage plants, with additional stages added between the feed inlet and the brine outlet. Individual plant designs may differ in some details from the typical plant described here.

531-3.1.1.1 Principles of Operation. In flash-type plants seawater is heated in a series of heat exchangers and subsequently discharged into the first-stage flash chamber. Since the pressure in the first-stage flash chamber is lower than the saturation pressure corresponding to the temperature of the feed, a portion of the feed flashes or vaporizes as it passes through the first-stage flash chamber. The vapor rises through a moisture separator or mesh-type demister and is condensed on the first-stage condenser tubes by the cooler seawater flowing through them. The condensed vapor (or distillate) then falls into the first-stage distillate trough. The remaining unflashed feed (brine) enters the second stage through restrictions in the bottom of the flash chamber. Since the brine is now at the saturation temperature of the first-stage vacuum and the second-stage flash chamber is at a lower pressure, a portion of the brine again flashes. Distillate is formed and collected in the second-stage distillate trough in the same manner as in the first stage. The distillate pump removes the distillate (formed in both stages) from the second-stage distillate trough. The remaining brine in the bottom of the second-stage flash chamber is pumped overboard. This subject is discussed more fully under the individual circulating system descriptions.

531-3.1.1.1.1 A constant rate of distillate production will be maintained with a constant generating steam pressure above the orifice plate in the steam line to the feedheater. Increasing or decreasing this pressure will increase or decrease the quantity of the feed pumped through the unit and the temperature of the feed to the first stage. A change in the pressure above the orifice will produce a corresponding change in distillate production.

531-3.1.1.1.2 The flash-type distiller has no separate condenser cooling circuit. The feed is used as distillate cooler, stage condenser, and air ejector condenser coolant, picking up heat in the process. It is heated in the feedheater to its terminal temperature and then sequentially directed through all of the stages. All of the heat input to the seawater is sensible heat. The pressure that suppresses boiling is maintained until the feed is discharged into the first-stage flash device. The quantity of freshwater produced depends on the quantity of feed entering the first-stage flash chamber and the total reduction in feed temperature in the flashing process. The ratio of distillate produced to feed through a flash-type distilling plant is approximately 1 gallon of distillate per 10 to 20 gallons of feed. This ratio is independent of the number of stages but varies directly with the seawater temperature. Flash-type distilling plants on Navy surface ships range in capacity from 6,000 to 100,000 gallons per day.

531-3.1.1.1.3 Flash-type distilling plants have the following advantages over boiling distillers:

a. Low scaling and corrosion rates because no boiling occurs on heat transfer surfaces, and brine is concentrated to only 5 to 10 percent above normal seawater.

b. Operation can be at full capacity for long periods

c. No brine level or density control required

d. Easy to automate.

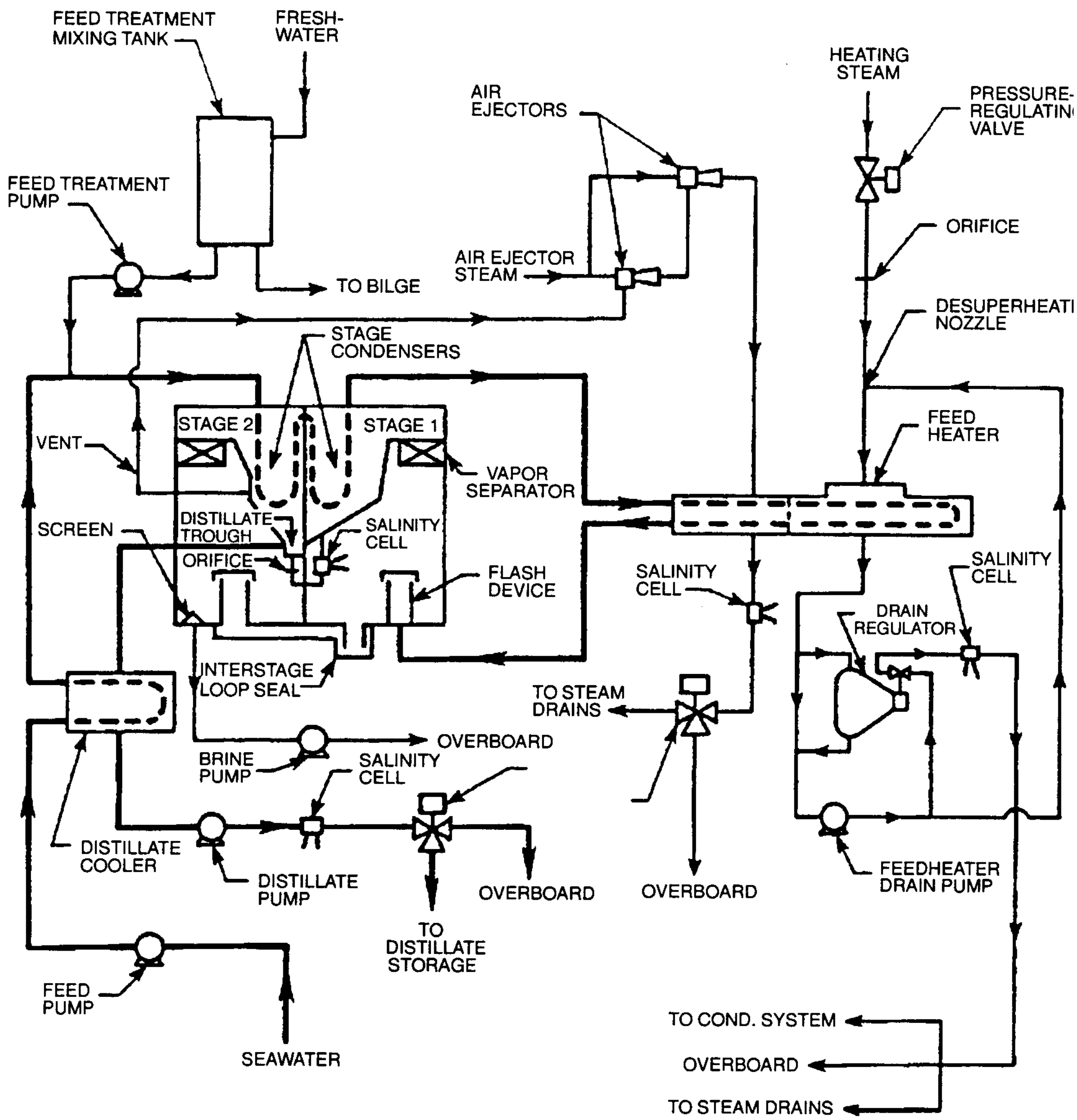


Figure 531-3-1 Diagram of a Two-Stage Flash-Type Distilling Plant

531-3.1.1.1.4 Disadvantages of flash-type plants are:

a. Most effective operation is with a low-pressure steam heat source and therefore do not readily adapt to diesel engine heat recovery or electric heaters

b. High gas release (carbon dioxide, etc.) in the first stage requiring larger air ejectors

c. High feed rates resulting in high chemical consumption.

531-3.1.1.2 Internal Arrangements. The shell of a flash-type plant is constructed of welded copper nickel alloy (and is welded to a structural steel frame). It is divided into two compartments of equal size to form the two stages. The first- and second-stage compartments are connected at the bottom by loop seals to provide feed flow from the first stage to the second stage, but prevent vapor from flowing between stages. These assist in maintaining stage differential pressure. These compartments are also connected at the top, normally through an orifice sized to provide proper venting of the first-stage compartment. This also aids in maintaining proper stage differential pressure.

531-3.1.1.3 External Arrangements. The air ejector, distillate cooler, and air ejector condenser/feedheater are normally mounted on the shell. These components are connected through piping arranged so that it will not interfere with stage access or block the view through the sight glasses. In some units a drain regulator is installed in the distillate line between the first and second stages in place of the loop seal and orifice arrangement. Feed, brine, distillate, and feedheater drain pumps are normally installed and arranged to take advantage of the limited space, minimize suction piping restrictions, and maintain the pump's required submergence head. Pressure, temperature, and salinity-measuring devices are located as necessary to monitor the distilling plant's operation.

531-3.1.2 CIRCULATING SYSTEMS. The circulating systems for flash-type distilling plants are as follows.

a. Generating-steam circuit

b. Vapor circuit

c. Distillate circuit

d. Air removal circuit

e. Seawater feed circuit

f. Brine circuit.

531-3.1.2.1 Generating Steam Circuit. The steam supply source for the seawater feedheater may be auxiliary exhaust, steam bled from the turbines, or live steam reduced from boiler pressure. Where exhaust steam is used, provide means for automatically augmenting the supply with live or bleed steam whenever the amount of auxiliary exhaust is insufficient to obtain the desired distilling plant capacity. Steam pressure to the seawater feedheater is controlled by a regulating valve (adjustable over the desired pressure range of a particular unit). An orifice plate is downstream of this valve to provide a constant flow of steam to the seawater feedheater shell at a pressure below atmospheric. As the steam enters the shell of the seawater feedheater, it condenses on the outside of the tubes and thereby transfers heat to the seawater in the tubes. The condensate is removed from the heater shell by a drain pump (by way of a drain regulator).

531-3.1.2.1.1 When the supply steam pressure is reduced, as it passes through the regulating valve, superheating of the steam results. A high degree of superheat may lead to operating difficulties. A desuperheater is installed in the steam line, normally below the orifice, and condensate for desuperheating is supplied from the discharge of the seawater heater drain pump.

NOTE

Fresh water from the potable water system or evaporator distillate shall not be used for desuperheating.

531-3.1.2.1.2 The flow of steam through an orifice is constant for a given upstream pressure, provided the downstream pressure is not greater than approximately 58 percent of the upstream pressure. For higher downstream pressures the flow falls off very rapidly. For a clean heater, a shell vacuum of 14 to 16 inches of Hg is normal. As deposits accumulate on the tubes, the steam does not condense as rapidly for a given temperature difference (between steam and feed temperatures). Since it enters the shell at the same rate, however, it accumulates in the shell and decreases the vacuum. As the vacuum decreases the temperature difference increases, and the rate of condensation increases to equal the rate of the steam admission. When the shell vacuum has been reduced by this process to 0 or 1 inch Hg, the heater tube surface will require cleaning if rated output is to be maintained. Plant output is directly related to the amount of heat transfer that occurs in the feedheater. This heat transfer is controlled by regulating steam pressure before the orifice, by changing the amount of desuperheating flow, and (in some plants) by allowing steam to bypass the orifice.

531-3.1.2.2 Vapor Circuit. In passing through the first-stage flash device the pressure of the feed is reduced to the pressure in the first-stage chamber, causing some of the feed to flash into vapor. The flashing process reduces the temperature of the feed since the latent heat of vaporization comes from the feed itself. The separator/demister removes any seawater particles from the vapor. After emerging from the separator (or demister), the vapor condenses on the tubes of the stage condenser, transferring heat to the seawater feed in the tubes.

531-3.1.2.3 Distillate Circuit. The distillate formed on the outside of the first-stage condenser tubes drains to the distillate trough in the bottom of the condenser. From there it flows through a loop seal and orifice, or drain regulator, over a salinity cell to the second-stage condenser. The loop seal and orifice prevent blowby of vapor from the first-stage condenser to the second-stage condenser. The distillate from the first stage flows into the bottom of the second-stage condenser where a small portion flashes because of the lower pressure of the second stage. The vapor flashed in the second-stage flash chamber rises and passes through a vapor separator, or mesh demister, into the second-stage condenser, where it condenses on the outside of the tubes and combines with the distillate from the first stage.

531-3.1.2.3.1 The total distillate of both stages is drained from the second-stage distillate trough by the distillate pump. The discharge of this pump passes over a salinity cell and into a distillate cooler, where it is cooled by the incoming seawater feed. (Some units have distillate cooler sections built into the second-stage heat exchanger, and some eliminate the distillate cooler completely.) After emerging from the distillate cooler, the distillate passes over a salinity cell that controls a solenoid-operated trip valve. Depending on the purity of the distillate as it passes over this salinity cell, the trip valve will direct it overboard or through the distillate watermeter to the ship's freshwater system or reserve feed system.

531-3.1.2.4 Air Removal Circuit. Normally, a two-stage air ejector is used to maintain the required vacuum in the second-stage distiller condenser. This unit removes the noncondensable vapors and air that enter the system in solution in the feed and by leakage at the vacuum joints. Steam for both ejectors is supplied from the auxiliary steam line. The first air ejector takes suction from the coolest portion of the second-stage distiller condenser. The second air ejector takes suction from the discharge of the first air ejector and discharges the gases and steam into the air ejector condenser, where the heat is absorbed by the seawater feed. The noncondensable vapors escape through the vent in the top of the condenser shell. The condensate is discharged over a salinity cell and, depending on its purity and the plant design, is routed to the steam drain collecting system, the feedheater drain pump, the condensate system, or the bilge.

531-3.1.2.5 Seawater Feed Circuit. The feed for the distilling plant is supplied from the sea by means of a suction sea chest. The water is picked up by the seawater feed pump and discharged through a suitable strainer to the tubes of the distillate cooler. The feed is preheated as it passes through the distillate cooler, second-stage condenser, first-stage condenser, and air ejector condenser. The final heating takes place in the seawater feedheater, where low-pressure steam heats the feed to its required terminal temperature. The heated feed then passes through the feed regulating valve and into the first-stage flash chamber.

531-3.1.2.6 Brine Circuit. Any seawater feed not vaporized in the first stage exits through an external loop seal into the second-stage flash chamber. Since the second stage is at a lower pressure (higher vacuum) than the first stage, an additional portion of the feed will vaporize in the second-stage flash chamber. Releasing the flashed vapor in the first and second stages increases the density of the feed, converting it into brine. The brine is pumped out of the last-stage shell and discharged overboard by the brine overboard pump. On some units the brine pump suction is protected with either an internal or an external screen.

531-3.2 OPERATION

531-3.2.1 GENERAL. Stability is the key to successfully operating any distilling plant. Keep all controllable parameters in a steady state. Make any changes to the feed flow rate in very small steps to cause minimum fluctuation in the plant. Do not allow the seawater feed terminal temperature to exceed 175°F unless necessary to produce the rated capacity. Higher temperatures will greatly increase the rate of scale formation. Feed temperature cannot be controlled after the feed leaves the seawater feedheater, as internal temperatures and pressures are self-governing and are established by the plant design. To determine the correct temperature/pressure for a given condition of a particular plant, check the heat balance diagram in the manufacturer's technical manual.

531-3.2.2 OPERATION IN CONTAMINATED WATER. When operating in contaminated or brackish freshwaters, the salinity-indicating system is of little value in protecting the purity of the distilled water. The low salt concentration in the feed means that high salinity would not necessarily occur when carryover, priming, or leakage takes place. Under these circumstances, use the distilling plant only when absolutely necessary. When operating in such waters, the feed terminal temperature shall be 165°F or higher. This will sterilize the seawater feed and any carryover or priming will not create a bacteriological hazard. The possibility of contamination still exists, however, because of the possibility of a leaky tube or joint in any of the stage condensers or distillate cooler.

531-3.2.2.1 The medical department representative on the ship should be made aware of this possibility. Unless otherwise determined by suitable test, all water in harbors, rivers, inlets, bays, and the open sea within 12 miles of the entrance to such waters and all landlocked waters shall be considered contaminated. In other areas, the fleet surgeon or his representative may declare the water to be contaminated if local conditions warrant such action.

531-3.2.2.2 Responsibility for determining the purity of potable water rests with the medical department representative, who in turn shall be guided by Chapter 6, **Water Supply Afloat,** of NAVMED P-5010-6, **Manual of Naval Preventive Medication.** This manual contains detailed procedures for inspecting and correcting potable water contamination.

531-3.2.3 SCALE FORMATION AND PREVENTION. During the evaporation process that produces distilled water from seawater, insoluble minerals are formed in the water. These minerals may deposit on the heating surfaces and form insulating scale. This is the greatest single obstacle to the continuous production of distilled water. Except under emergency conditions, do not force a plant beyond its rated capacity because higher pressures will be required and the resulting higher temperatures will cause more rapid scale formation. The rate of buildup and the composition of the deposits also depend on such factors as brine density, feed treatment, sea versus shore feed, and flow rates. Scale formation is indicated by consistently rising temperatures in the distilling plant stages and seawater feedheater shell (with a corresponding decrease in vacuum). An increase in the steam pressure required at the seawater feedheater to produce the specified feed terminal temperature also indicates scaling.

531-3.2.3.1 Scaled heat exchanger tubes can be cleaned chemically by circulating a diluted acid solution through or on the tubes. Acid cleaning will cause a slight but acceptable loss of some metal and will have a slight effect on gasket materials. This low-level acid attack should not reduce distilling plant life significantly, provided that chemical cleaning is used only when necessary and in the recommended manner. Do not consider acid cleaning to be a cure-all for all distilling plant problems or a substitute for all other distilling plant maintenance. Do not neglect seawater feed treatment with the expectation that heavy scale can be removed by acid cleaning. Acid cleaning procedures are discussed in paragraphs 531-3.4.7.1 through 531-3.4.7.1.2.

CAUTION

Concentrated scale preventive compound is strongly alkaline. Avoid contact of the liquid with skin or eyes. Wash hands thoroughly after using. In case of contact with eyes, flush with fresh water for at least 15 minutes. Report to sick bay immediately.

531-3.2.4 FEED TREATMENT. Scale preventive compound is another means of controlling scale formation. This material helps to retard scale formation and foaming in distilling plants, providing higher plant output and less downtime over extended periods. The only authorized distiller scale preventive compound for surface ships is per DOD-D-24577 and is available from the Navy Supply System under National Stock Number (NSN) 9G6850-00-173-7243. Ships not originally equipped with chemical injection equipment conforming to MIL-P-21397 should install such equipment through ship alteration (SHIPALT). The required mixing/measuring tank and proportioning injection pumps are available under NSN 1H4610-00-678-33 42.

531-3.2.4.1 Mixing Proportions. Use 1 pint of scale preventive compound for each 4,000 gallons per day of distilling plant capacity. The total amount of scale preventive compound should be combined in the mixing tank with enough freshwater to make 24 gallons of solution.

NOTE

All plants require 24 gallons of solution, regardless of plant capacity.

531-3.2.4.2 Injection Rate. With the proportioning pump, inject the prepared solution into the feed circuit at the rate of 1 gallon per hour. Record the mixing tank level hourly to confirm the feed rate.

531-3.2.5 OPERATING NOTES. The following notes are general and apply to all flash-type plants. Refer to the manufacturer’s technical manual for detailed information.

531-3.2.5.1 Brine Density. Brine density is not considered an operating parameter for flash-type distillers.

531-3.2.5.2 Water Level. The first- and second-stage flash chambers should operate empty or nearly empty. Carrying a water level in the flash chambers can lead to flooding of the stages. The brine pump discharge valve may be throttled, if necessary, to ensure that the pump does not run dry.

531-3.2.5.2.1 Drain regulator gage glasses should show a level during normal operation. An empty or full glass indicates a drain regulator malfunction or air leak in the associated piping system. Gage glasses on brine and distillate pump suction lines should operate empty or with a water level anywhere in the glass. A flooded glass indicates pump malfunction or air leaks in the associated piping. An interstage loop seal should operate with a water level anywhere in the gage glass or above it.

531-3.2.5.3 High Salinity. Distillate having a salinity content over 0.065 equivalents per million (epm) of chloride shall be discharged to the bilge. After diverting the contaminated distillate to the bilge with the solenoid-operated trip valve, determine the salinity of the distillate discharge from each stage condenser to locate the cause of the contamination. Seawater leaking into the distillate and priming is a major cause of contamination.

531-3.2.5.4 Carryover. Carryover is one of the main causes of distillate contamination. The following plant conditions cause carryover:

a. A high water level in the flash chambers resulting from improper operation of the brine overboard pump can cause overloading of the vapor separator.
b. Reducing the feed flow to very low levels can cause flashing to occur ahead of the inlet orifice. Such flashing releases very fine moisture droplets in the form of a fog or mist that can pass through the vapor separator/mesh demister, resulting in high salinity distillate from the first stage.
c. A fluctuating vacuum in the second-stage flash chamber can be caused by faulty air ejector operation from either low steam pressure or wet steam to the nozzle. Less common causes of a fluctuating vacuum are an incorrectly operating distillate pump and excessive or erratic air leaks at vacuum joints or pump glands.

531-3.2.5.4.1 Tube/tube joint leakage in stage condensers or in the distillate cooler may also contaminate the distillate. Condensate from the air ejector condenser and seawater feedheater drain may occasionally show salinity in excess of 0.065 epm of chloride. High salinity in the air ejector condenser drain may be due to a high gas content or to a leaky tube/tube joint. High salinity in the seawater feedheater drain would indicates a leaky tube/tube joint.

531-3.2.5.4.2 When high salinity conditions persist, with a resulting drop in distillate output, secure the plant and conduct a hydrostatic test according to Appendix A. Correct any leaks found before restarting the plant.

531-3.2.6 OPERATING PROCEDURES. Refer to the manufacturer's technical manual for detailed procedures. The following procedures are general and apply to all flash-type distilling plants:

531-3.2.6.1 Startup Procedure

1. Lift relief valves by hand before starting.
2. Ensure that all strainers are clean.
3. Ensure that all thermometers, pressure gages, vacuum gages, salinity cells, and associated alarms are operating correctly.
4. Ensure that all gage and sight glasses are clean.
5. Ensure that all drains and sampling connections are closed.
6. Check the manually operated handwheel on the drain regulators for movement, binding, or other abnormalities.

7. Ensure that the solenoid-operated trip valve is set to pass water to the drain system during plant startup.
8. Ensure that all bypass valves are closed.
9. Open vents on pumps.
10. Ensure that all inlet and outlet valves on flowmeters and heat exchangers are open.

CAUTION

Starting the pump with the discharge valve open may damage the heat exchanger gasket and water box/feed distribution equipment. Do not flood the shell.

11. Before starting the seawater feed pump, ensure that the first-stage seawater feed regulating valve is cracked open (one or two turns off the seat) and that the pump discharge valve is closed.
12. When the pump is running up to speed with good discharge pressure, slowly open the discharge valve.
13. Start the brine pump when water is observed in the last-stage flash chamber.
14. Start the seawater feed treatment pump and ascertain its correct operation before opening the steam inlet valve to the seawater feedheater.
15. Start the air ejector.
16. Admit steam to the seawater feedheater.
17. Start the drain pump.
18. Start the distillate pump.
19. Set the solenoid-operated trip valve.
20. Align the drains.

531-3.2.6.2 Securing Procedure

1. Trip the solenoid-operated valve and direct distillate to the bilge or contaminated drain system.
2. Route condensate (drains) from the air ejector condenser and seawater feedheater to the contaminated drain system.
3. Secure the steam valves to the air ejector.
4. Secure the steam valves to the seawater feedheater.
5. Secure the seawater feedheater drain pump and its suction/discharge valves.
6. Secure the desuperheater condensate control valve.
7. When the distillate pump loses suction, secure the distillate pump and its suction/discharge valves.
8. Continue circulating seawater for approximately 5 minutes to cool the unit, then secure the seawater feed pump and its suction/discharge valves and the first-stage feed regulating valve.
9. Secure the feed treatment pump and its suction/discharge valves.
10. When the shell has been pumped down, secure the brine overboard pump and its discharge valve.
11. Secure electric power to the salinity indicating panel.

12. Secure the inlet and outlet valves to the freshwater meter.

13. If the shutdown is to be for a prolonged period, drain the entire unit.

531-3.3 TROUBLESHOOTING GUIDE

531-3.3.1 Common operating problems, their symptoms, and their remedies are identified in Figure 531-3-2.

531-3.4 MAINTENANCE

531-3.4.1 GENERAL. Full output can be maintained for relatively long periods without interruption only if every part of the plant is maintained in reliable operating condition. This can be ensured by periodic inspections, tests, cleaning, and replacement of worn parts. Refer to the assigned PMS, and test and inspect as specified by the applicable maintenance index page (MIP).

531-3.4.2 AIR EJECTORS

531-3.4.2.1 Strainers. The air ejector steam strainer is usually an integral part of the air ejector. Inspect it regularly and clean whenever necessary. Failure to keep the strainer clean will cause a reduced and fluctuating vacuum. If a strainer is damaged, replace it with a new one.

Step	Faulty Components	Symptom	Probable Cause(s)	Remedy
1		Improper salinity distillate	Improper heat balance	Establish pressures, temperatures, and flow rates according to manufacturer's technical manual. Stabilize operation.
			Salinity indicating equipment out-of-calibration	Chemically test distillate. If salinity cells are reading inaccurately, conduct cell Planned Maintenance System (PMS).
			Foaming in evaporator	Ensure proper feed treatment. If feed is of high organic content or other unusual substance (most likely to occur in port), secure operation until seawater conditions improve.
			Leaky distillate trough	With unit secured, fill trough with water and check for leaks, then repair.
			High water level in stages	If flooding occurs in first or intermediate stages, check feed temperature, equalization of pressure between stages, and air leaks. If flooding occurs in last stage, increase brine flow overboard. See step 3B if unable to lower level.
			Air ejector malfunction	See step 4.
			Tube leak in stage condenser or distillate cooler	See steps 5 and 6.
			Carryover	See step 8.

Figure 531-3-2 Troubleshooting Guide for Flash-Type Distilling Plants (Sheet 1 of 7)

Step	Faulty Components	Symptom	Probable Cause(s)	Remedy
1 (Cont)			Instrumentation calibration	See step 9.
			Improperly installed feed distribution equipment inside evaporator	Install according to technical manual.
2		Low distillate output (as determined by meter and tank soundings).	Improper heat balance	Establish pressures, temperatures, and flow rates according to technical manual. Stabilize operation.
			Distillate transfer valve leaking to waste system	Repair or replace.
			Temperature of steam supply to feedwater excessive; that is 10 °F or more above heater shell temperature	Adjust desuperheater water flow.
			Stage condenser(s) flooding	See step 3A.
			Low stage vacuum	See step 4. Secure unit and hydrostatically test.
			Feedheater malfunction	See step 7.
			Instrumentation out-of-calibration	See step 9.
			Improperly installed feed distribution equipment inside evaporator	Install according to technical manual.

Figure 531-3-2 Troubleshooting Guide for Flash-Type Distilling Plants (Sheet 2 of 7)

Step	Faulty Components	Symptom	Probable Cause(s)	Remedy
3	Pumps (all)	Noise and vibration	Excessive misalignment of pump to motor. Refer to technical manual Maintenance Requirement Cards (MRCs) for maximum allowed values	Realign if excessive.
			Excessive misalignment of piping to pump	Ensure that piping shows no strain on casing.
			Binding at packing/seals or faulty bearing. If coupled, faulty coupling. If external inspection is not conclusive, open pump: a. Inspect for rubbing. b. Inspect for damaged bearings. c. Inspect for foreign matter. d. Inspect for impeller erosion. e. Remove rotating element and check for straightness and proper balance.	Repair discrepancy.
3A	Distillate pump	Flooding in distillate trays and pumps discharge very low or in vacuum	Improper valve alignment	Open or close valves as necessary.
			Improper direction of pump rotation	Reverse motor rotation.

Figure 531-3-2 Troubleshooting Guide for Flash-Type Distilling Plants (Sheet 3 of 7)

Step	Faulty Components	Symptom	Probable Cause(s)	Remedy
3B	Brine pump	Flooding in last stage and pump discharge very low or in vacuum	Air leak at shaft seal	Check for air leak, utilizing potable water hose. When water is applied to leak, an immediate increase in pump discharge pressure normally occurs and flooding is eliminated. If air leak i indicated: a. Ensure sealing water to mechanical seals/packing. b. Ensure alignment of packing lantern ring with sealing water inle c. Ensure seal between shaft/shaft sleeve.
			Excessive wearing ring clearance	Open, inspect, and repair as necessa
3C	Feedheater drain pump	Flooding in distillate trays and pumps discharge very low or in vacuum	Improper venting	Ensure vent piping is clear of obstruction and free of leaks
3D	Feed Pump	Excessive feedheater temperature when feed valve is wide open.	Excessive wearing ring clearances/impeller erosion	Check pump discharge pressure (shu off head) with discharge valve closed. If pressure is 10 psig or more below technical manual value, open, inspect and repair as necessary.
		Steam discharge from air ejector condenser vent		
		NOTE: These indications may also be caused by excessive scale in the heater and condenser. See step 7.		

Figure 531-3-2 Troubleshooting Guide for Flash-Type Distilling Plants (Sheet 4 of 7)

Step	Faulty Components	Symptom	Probable Cause(s)	Remedy
4	Air ejector	Loss of or low vacuum: Last stage temperature is high and temperature difference between last and next to last stage is low. Refer to technical manual for values.	Steam pressure to air ejector is not according to technical manual.	Determine cause of pressure discrepancy and correct.
			Air ejector nozzles faulty.	Inspect air ejector nozzles for: a. Scale in throat b. Erosion (wire drawn) c. Location in proper stage d. Steam bypass at nozzle to chest. Correct discrepancy.
			Air ejector condenser faulty as evidenced by: a. Large amount of steam from vent (based on operator experience). b. Large amount of air from vent (based on operator experience).	Inspect for low feed rate and malfunctioning feed pump. See step 3D. Inspect for excessive scale. Hydrostatically test, including feed-heater, to find air leaks.
			Excessive moisture in steam supply.	Verify all low point drains and traps in steam supply are functional.
			Air ejector discharge valve is binding, has loose flapper, or is installed backwards.	Eliminate discrepancy.
5	Interstage condensers	High salinity.	Saltwater leak in condenser.	While operating, use the salinity indicating system to identify the faulty stage. Hydrostatically test the suspected stage condenser. Repair leaks.

Figure 531-3-2 Troubleshooting Guide for Flash-Type Distilling Plants (Sheet 5 of 7)

Step	Faulty Components	Symptom	Probable Cause(s)	Remedy
6	Distillate cooler	High salinity at cooler discharge while maintaining satisfactory salinity to the cooler.	Saltwater leak in cooler.	Hydrostatically test cooler. Repair leak.
7	Feedheater	Heater shell temperature above 206 °F or vacuum is less than 3 inches mercury (Hg). For nuclear ships, refer to equipment technical manual.	Temperature of steam to feedheater excessive; that is, 10 °F or more above shell temperature	Adjust desuperheater water flow.
			Excessive scale on watersides (last pass normally most heavily scaled).	Remove scale using acid and mechanical means.
			If no scale is present, inspect for an air leak.	Hydrostatically test feedheater and steam piping, including the critical flow orifice.
			Hot well flooded.	See step 3C.
			Feed system malfunction.	See step 3D.
		Impure condensate from feedheater drain	Saltwater leak in feedheater.	Hydrostatically test feedheater steamside with water boxes removed. Repair.

Figure 531-3-2 Troubleshooting Guide for Flash-Type Distilling Plants (Sheet 6 of 7)

Step	Faulty Components	Symptom	Probable Cause(s)	Remedy
8A	Demisters	High salinity	Carryover as a result of gaps in demister material	Inspect demisters. They should be completely tight at ends and sides. If gaps exist, attempt to stretch demisters in place. If unsuccessful, remove demisters, reshape, and reinstall gap-free. If material is beyond repair, install new demisters gap-free.
8A	Vapor separators	High salinity	Broken vanes and leaky joints	Repair or replace.
9	Instrumentation	Thermometer readings questionable. Vary significantly from proper operational values.	Out-of-calibration	Remove thermometers and lay them on work bench or other areas for 15 minutes; they should read within 3 °F of one another. Replace if unable to calibrate.
			Improper installation	Verify that thermometer stem extends to the bottom of the well. Replace if too short.
		Pressure/vacuum gage readings questionable. Vary significantly from proper operational values.	Out-of-calibration	Verify calibration. Use steam tables and compare vacuum gage readings to temperature readings for instruments in same area. Replace if unable to calibrate.

Figure 531-3-2 Troubleshooting Guide for Flash-Type Distilling Plants (Sheet 7 of 7)

531-3.4.2.2 Nozzles. A clogged or scored air ejector nozzle will cause the same unsatisfactory operation as a clogged strainer. Clean nozzles with a nozzle reamer, if provided, or with a wooden stick or soft wire. Never use a file or other sharp instrument that might score and ruin the nozzle. Nozzles may be removed for cleaning and inspecting, but cleaning alone can be accomplished with the nozzle in place. Replace a scored nozzle with a new one.

531-3.4.3 DEMISTERS. If they are correctly installed and the distilling plant is operated within rated capacity, the demisters should not require removal. Periodically removing the access covers in the main shell and spraying the demisters with a high-velocity stream of hot freshwater, however, will remove all loose and moderately adherent scale. Occasionally, the demister may be fouled or scaled to the extent that the flashed vapor is severely restricted as it passes to the condenser. In these cases, remove the demisters for mechanical or chemical cleaning. Ensure that the demister is properly aligned when reinstalling in the shell and that no rat holes or gas lanes exist.

531-3.4.4 STRAINERS. Inspect and clean or replace strainers in accordance with the ship's Planned Maintenance System (PMS).

531-3.4.5 HYDROSTATIC TEST. Hydrostatically test the entire system whenever air leakage is suspected. Also test the unit after it has been dismantled for cleaning or overhaul. Refer to Appendix B for a hydrostatic test procedure.

531-3.4.6 PUMPS. The speed and direction of rotation of each pump should be checked when first starting a new plant and every time electrical work has been performed on the pump motor. All pump connected piping shall be firmly supported to prevent the piping load from stressing the pump casing, which could cause pump misalignment and shorten the pump's service life. All piping shall also be airtight since air entering these lines, even though not sufficient to affect plant vacuum, can cause the pump to lose suction. Refer to the applicable pump manufacturer's technical manual for pump details.

531-3.4.7 CLEANING. Distilling plants that vent the seawater feedheater shell to the first-stage shell require cleaning whenever the seawater feedheater shell vacuum drops to zero and a positive pressure starts to build. For distilling plants that vent the seawater feedheater shell to the atmosphere, however, cleaning is required when the seawater feedheater shell pressure reaches 4 psig. Either chemical or mechanical cleaning is acceptable.

531-3.4.7.1 Chemical Cleaning. Chemical cleaning is faster, more economical, more effective, and less harmful to the distilling plant than mechanical cleaning. It consists of circulating a heated diluted acid solution through the seawater feed and brine circuits of the system. The distilling plant should be acid cleaned according to either Appendix C or Appendix D.

531-3.4.7.1.1 Citric acid is the preferred method of chemical cleaning for flash-type distillers. It is less harmful to tubes and gaskets, can be performed by the ship's force, and does not require plant shutdown. Citric acid cleaning does, however, have the following limitations:

a. It is not approved for use in port since the brine discharged overboard during citric acid cleaning will not meet environmental regulations.

b. It will not remove heavy scale. In some installations, waiting until the seawater feedheater shell vacuum falls to 0 or 1 inch Hg (as suggested in paragraph 531-3.1.2.1.2) will result in scale accumulations too heavy to be removed by citric acid cleaning. In these cases, the ship's force should determine the correct seawater feed vacuum (or time interval) for citric acid cleaning.

531-3.4.7.1.2 If citric acid cleaning is ineffective, clean with sulfamic acid or mechanically.

CAUTION

Use the heat exchanger tube cleaning tool as an emergency measure only. Tube damage may result from its use.

531-3.4.7.2 Mechanical Cleaning. If chemicals are unavailable or chemical cleaning will not satisfactorily remove the scale, a heat exchanger tube cleaning tool is available for removing scale from heat exchanger tubes of the seawater feedheater (Figure 531-3-3).

531-3.4.7.2.1 Remove the water heads from the seawater feedheater. Insert the cleaning tool in the tube and drive it with a 250 to 300 rpm reversible motor. Feed a light stream of water into the opposite end of the tube to wash away the scale removed by the tool. A light stream of compressed air may be used in place of water. Do not drive the tool too fast and be sure that the tool is straight when initially inserted into the tube. Perform a 10-psig, low-pressure hydrostatic test on the shell of the seawater feedheater before replacing the heads. See Appendix B for the hydrostatic test procedure.

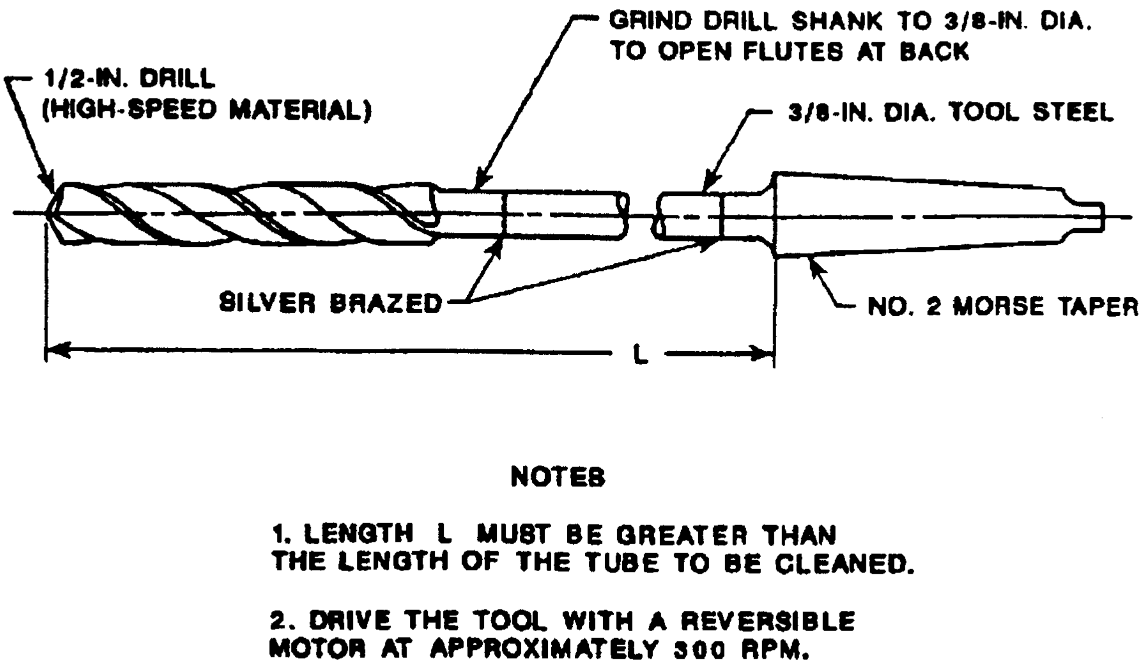


Figure 531-3-3 Heat Exchanger Tube Cleaning Tool

APPENDIX A.

GLOSSARY

Brine — **The feed remaining after some vapor has been liberated; that is, water in which the concentration of chemical salts is higher than in the seawater feed.**

Carryover — **Salt-laden moisture droplets carried with the vapor through the moisture separators or demisters.**

Condensate — **The liquid produced by condensing heating and air ejector steam.**

Condensation — **The process of cooling (condensing) the vapor produced by evaporation to produce fresh water (distillate).**

Desuperheated steam — **Superheated steam to which liquid water has been added to reduce the degree of superheat.**

Distillate — **The liquid produced by condensing the vapor formed during the evaporation of seawater. This is the final product of a distilling plant.**

Distillation — **The total process the distilling plant performs, including evaporation and condensation.**

Effect — **Distilling plant compartments are called effects when the vapor produced in one compartment is used as the heat source for (and thus condensed in) the next compartment. This applies to multieffect submerged-tube or vertical-basket distillers.**

Evaporation — **The process of separating seawater into vapor and brine, either by boiling or by flashing.**

Feed (evaporator feed) — **Seawater supplied to the distilling plant, for distillation.**

Heat balance The optimum relation of pressure, temperature, and flow for which a unit is designed.

Heat recovery Use of waste heat from another energy source, such as diesel engine cooling jacket water.

Latent heat Heat addition or removal that causes a physical change of state while the temperature and pressure remain unchanged. Latent heat addition is required for vaporization and is given off during condensation.

Priming See carryover.

Salinity The chemical salts in solution in the distillate/condensate, measured by an electric cell and/or chemical test. Salinity is measured either in equivalents per million (epm) or parts per million (ppm) and used as an indicator of purity.

Saturated steam
Vapor that is in contact with its liquid source. The temperature of saturated steam steam will always be the saturation temperature corresponding to its current pressure.

Saturation pressure
The pressure (corresponding to a given temperature) at which water can exist as pressure liquid or vapor.

Saturation temperature
The temperature (corresponding to a given pressure) at which water can exist as a temperature liquid or vapor.

Sensible heat Heat addition or removal that causes a temperature change.

Stage In flash-type distilling plants the compartments are called stages when the vapor is produced and condensed within the same compartment.

Superheated steam
Vapor that is not in contact with its liquid source and has been heated to a steam temperature above its saturation temperature. The difference between the temperature of superheated steam and the saturation temperature corresponding to its current pressure is called the degree of superheat.

Terminal temperature
Temperature of the feed as it enters the first stage/effect.

Vacuum A pressure less than atmospheric. Vacuum is measured downward from atmospheric pressure. Thus, the higher the vacuum, the lower the pressure.

APPENDIX B.

HYDROSTATIC TEST PROCEDURE FOR LOW-PRESSURE DISTILLING PLANTS

531-B.1 GENERAL

531-B.1.1 Apply a shell-side hydrostatic test whenever an air leak is suspected or after reassembly following repairs.

531-B.2 TEST PROCEDURE

CAUTION

On flash-type units, do not attempt to hydrotest one stage at a time. Structural damage could result in the division wall and distillate tray structures.

531-B.2.1 Apply hydrostatic tests according to the following procedure:

1. Ensure that all electrical equipment such as pumps and salinity-indicating equipment is secured and tagged out.
2. Close all discharge valves on all pumps.
3. Secure all steam supply valves (air ejectors and auxiliary exhaust).
4. For units with rupture discs installed, remove the rupture disc and install a blank flange.

CAUTION

The relief valve diameter must be equal to or greater than the fill line diameter to ensure adequate relieving capacity.

5. Install a relief valve in the fill line between the fill valve and shell. Set the relief valve for 15 psig or 2 psig below the recommended relief valve setting, whichever is lower.
6. Select a convenient filling connection for attaching the hose and valves to the negative pressure side.
7. Secure the feed valve.
8. Remove the inspection plugs on all waterboxes for tube leakage inspection.
9. Install a damage control plug in the air ejector condenser vent to atmosphere, and secure the drain lines.
10. Reverse the check valve in the air ejector discharge line or blank the air ejector discharge line.
11. Open the vents on all effects or stages.

CAUTION

Cautiously monitor shell pressure gage while filling evaporator shell. Do not overpressurize evaporator shell. Hydrotest to 10 psig only. Do not hydrotest the evaporator using air pressure.

12. Slowly fill the evaporator shell with fresh water from the ship's fresh water system until water appears at the vents in each effect or stage. If testing with freshwater is unfeasible, fill the shell with seawater using the seawater feed pump. The brine overboard pump should be operating and the overboard discharge valve should be throttled to allow gradual filling. The brine overboard discharge valve can be regulated to permit the water level in the shell to rise and to prevent shell pressure from building beyond 10 psig.
13. Secure all vents.
14. Control pressure with the valve installed in the fill line. Hydrotest to 10 psig.
15. When the desired pressure has been obtained, carefully inspect all piping connections, gage glasses, pumps, tube joints, and the shell for any leakage. Hold pressure for at least 1 hour to ensure that any leakage under the shell insulation becomes evident. Inspect all tubes carefully for leakage through inspection ports in the waterboxes. Inspect gage connections and piping for leakage.
16. When all leaks have been identified, release pressure and drain unit. Correct all leaks; then rehydrotest, using the same procedure as proof of repair.

APPENDIX C.

ON-LINE CITRIC ACID CLEANING PROCEDURE

531-C.1 GENERAL

531-C.1.1 This on-line citric acid cleaning procedure provides for cleaning of submerged-tube, basket-type, and flash-type distilling plants at sea while boiler feedwater-quality distillate is being produced. This method is not authorized for use in port because the acidity of the brine exceeds the limits for discharge in port areas.

NOTE

The chemical reaction of citric acid and distiller scale produces carbon dioxide. This may contaminate the distillate and could adversely affect the demineralizer resin in saturated steam plant ships where the distillate is piped directly to the demineralizers. Saturated steam plant ships shall send the distillate to the potable water system or to the bilge while cleaning and for 2 hours after citric acid injection has been completed. Feedheater condensate or steam basket drains may be returned to the condensate system throughout the cleaning period, provided the condensate conductivity is within the specified limits.

531-C.1.2 The cleaning procedure involves injecting a citric acid solution into the seawater feed of the distilling plant. Injection is accomplished either with installed injection equipment or by vacuum drag. The citric acid reacts with distiller scale to form soluble products that are discharged with the distilling plant brine. Carbon dioxide is also given off by this reaction and is removed by the distilling plant air ejector.

531-C.1.3 Successful cleaning will normally be accomplished in 4 hours. If the cleaning is unsuccessful after 8 hours, open and inspect the distiller at the first opportunity. Remove a sample of the scale. Determine if the scale will dissolve in citric or sulfamic acid by placing one rounded teaspoonful of either acid into 8 ounces of water, heating the solution to approximately 150° F, and placing a piece of scale into the acid solution. Wear safety equipment such as safety goggles and chemical resistant gloves when handling the acids. Stir the solution occasionally while maintaining the 150° temperature. Observe the solution for evidence of bubbling or a decrease in scale sample size as indications that the scale is dissolving. If dissolution does not appear to be occurring, the scale sample should be analyzed, for example, by wet chemical methods or x-ray diffraction, for determination of the chemical makeup to establish an optimum removal method. NSWCCD Philadelphia can provide assistance with analysis of scale samples.

NOTE

Unnecessary use of this procedure may cause excessive tube metal waste. Do not begin citric acid on-line cleaning unless feedheater shell, first-effect tube nest, or basket pressure is above design values. The increase in this pressure will occur gradually when caused by scaling. Sudden increase in this pressure does not indicate scale or the need to clean the distiller. Before acid cleaning, the ship's force shall visually verify that scale is present. Submerged-tube and basket-type distillers shall be visually inspected through the viewing ports, and flash distillers shall be visually inspected by removing a handhole cover or zinc plug from the last pass of the seawater heater.

531-C.2 EQUIPMENT REQUIRED

531-C.2.1 The following equipment and materials are require for citric acid cleaning:

a. Chemical mixing tank with spigot; 30-gallon capacity, polyethylene, MIL-T-24494, **Tetrasodium-Ethylenediaminetetraacetate (EDTA) Water Treatment Chemical, Boiler, Shipboard Use,** NSN 1H0099-LL-HDH-Z482. This tank may be available in conventional steam ships as part of EDTA boiler acid cleaning equipment. Two are required for cleaning large evaporators. Tanks are not required for ships equipped with distilling plant chemical feed treatment systems. A piping arrangement is shown in Figure 531-C-1.

NOTE

Do not use a carbon steel, galvanized, or aluminum tank.

b. Acid stirrer (broom handle)

c. Compound vacuum/pressure gage, 30 inches of Hg vacuum to 30 psig with 1/4-inch taper pipe thread (NPT), NSN 9G6685-00-974-6532. This gage is not required for submerged-tube or basket-type distillers or if previously installed on the feed pump suction line for flash distillers.

d. Anhydrous trisodium phosphate, 25-pound drum, NSN 9G6810-01-082-5415. This is normally stocked on board steam propulsion ships for boiler water treatment.

e. Safety equipment:
   1. Face shield, NSN 9Q4240-00-542-2048
   2. Rubber gloves, NSN 9D8415-00-266-8677
   3. Rubber apron, NSN 9D8415-00-634-5023
   4. Dust mask, NSN 4240-00-629-8199

f. Citric acid, 50-pound drum, MIL-C-11029B, **Citric Acid, Technical, (Anhydrous),** NSN 9G6810-141-2942.

g. Scale preventive compound, DOD-D-24577,**Distiller Scale Preventive Treatment Formulations,** NSN 9G6850-00-173-7243.

531-C.3 SAFETY AND HANDLING PROCEDURES

531-C.3.1 PROPERTIES. The properties of citric acid and trisodium phosphate are described in the following paragraphs.

531-C.3.1.1 Citric Acid. Citric acid powder is irritating to the eyes, nose, respiratory tract, and skin. When moist, it reacts with most common metals, especially iron, to give off hydrogen gas, which is a fire and explosion hazard. In concentrated solutions it can severely irritate the skin and eyes. Prolonged contact with the skin may cause ulcers.

531-C.3.1.2 Trisodium Phosphate. Trisodium phosphate is a white, granular powder and is not a fire hazard. It can produce alkali burns on the skin and eyes. The effect is similar to that of lye, but less severe. If taken internally, nausea and vomiting, pain in the throat and stomach, weak pulse, pallor, and collapse may result.

531-C.3.2 SAFETY PRECAUTIONS. Both citric acid and trisodium phosphate are potentially hazardous chemicals and should be handled with care. Personnel handling and mixing these chemicals shall wear the following protective equipment:

a. Face shield

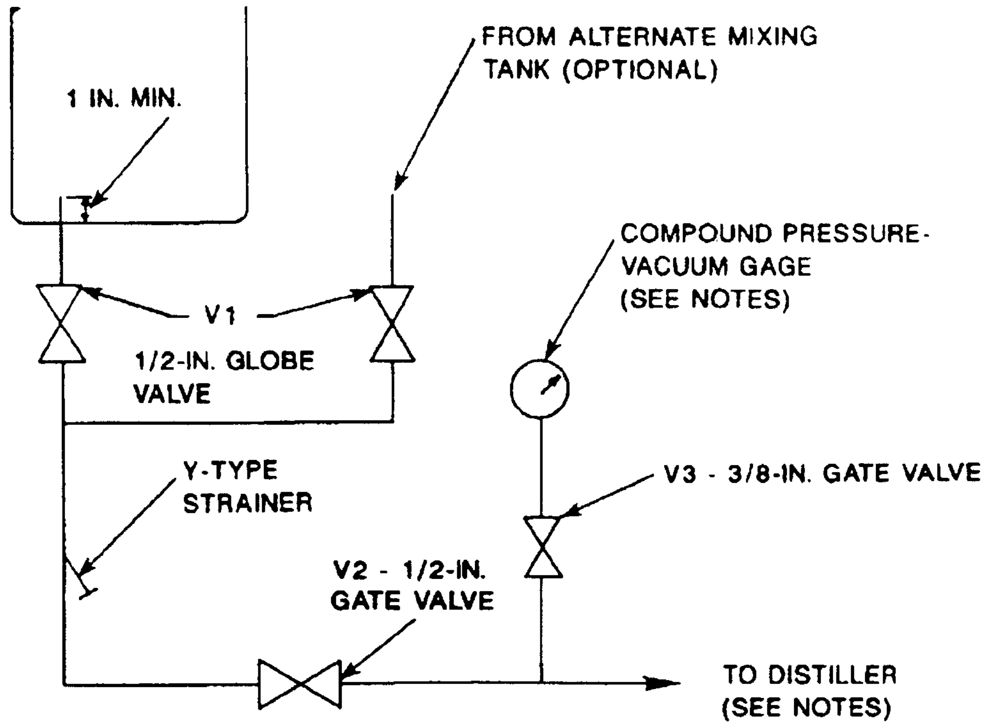
b. Rubber gloves

c. Rubber apron

d. Dust mask.

531-C.3.3 FIRST AID TREATMENT. The first aid treatment for citric acid and trisodium phosphate are described in the following paragraphs.

531-C.3.3.1 Citric Acid. In case of contact with acid, flush the skin immediately with plenty of water and remove all affected clothing. If eye contact occurs, flush eyes thoroughly with warm water and report to sick bay immediately. If acid has been swallowed, report to sick bay immediately.



NOTES

1. Cleaning System Connects to:
   a. First-effect vacuum drag connection (submerged-tube and basket-type distillers), or
   b. Suction gage connection on distiller feed pump (flash-type distillers), or
   c. Feed treatment proportioning pump suction (all types).
2. Compound pressure-vacuum gage not required on submerged-tube or basket-type distillers. Not required on flash-type distillers if already installed on feed pump suction line.

Figure 531-C-1 Piping Arrangement for Citric Acid Cleaning

531-C.3.3.2 Trisodium Phosphate. In case of accidental contact, wash the skin with a large volume of water at once. Flush eyes immediately with water for 15 minutes while lifting eyelids. Report to the sick bay immediately. Skin burns, after being washed with water, can be treated with diluted vinegar and again rinsed with water. If taken internally, report to sick bay immediately.

531-C.3.4 STORAGE. Store citric acid and trisodium phosphate in a dry, ventilated place. Containers shall be kept closed and plainly labeled.

531-C.4 SPILL AND CLEANUP PROCEDURES

531-C.4.1 When dry citric acid or tri-sodium phosphate is spilled, sweep it up and place it in a dry container for disposal (a closed plastic bag is acceptable). Always keep the chemical dry when not in use.

531-C.4.2 For small wet spills of citric acid (less than 1 gallon), flush to the bilge with water and pump overboard.

531-C.4.3 For large wet spills of citric acid (greater than 1 gallon), neutralize with trisodium phosphate (2 pounds of trisodium phosphate per gallon of citric acid solution spilled) and rinse to the bilge with water and pump overboard.

531-C.5 PREPARATION

531-C.5.1 The piping arrangement for injecting citric acid into the distiller is shown in Figure 531-C-1. Ships equipped with distiller chemical feed treatment systems may use the installed treatment system to inject citric acid, if the installed system is of adequate pumping capacity (values listed in Table 531-C-1 and Table 531-C-2). Ships that use their own installed injection equipment shall ensure that the tank suction connection is at least 1 inch above the tank bottom and shall verify that the appropriate Y-type strainer is installed.

531-C.5.2 Mark the mixing tank gage glass or fabricate a tank level-indicating stick to indicate the mixing tank level in 1-gallon increments.

WARNING

Citric acid can severely irritate the skin and eyes. Wear protective equipment. In case of contact, flush affected area with water and report to sick bay immediately. If swallowed, report to sick bay immediately.

Table 531-C-1 INITIAL CITRIC ACID FEED RATES FOR SUBMERGED-TUBE AND BASKET-TYPE DISTILLING PLANTS

Distiller Rated Capacity (Gallons per Day)	Citric Acid Feed Rate (Gallons per Hour)
4,000	0.6

Table 531-C-1 INITIAL CITRIC ACID FEED RATES FOR SUBMERGED-TUBE AND BASKET-TYPE DISTILLING PLANTS - Continued

Distiller Rated Capacity (Gallons per Day)	Citric Acid Feed Rate (Gallons per Hour)
8,000	1.4
12,000	2.0
20,000	3.4
30,000	5.0
40,000	6.6
50,000	8.4

Table 531-C-2 INITIAL CITRIC ACID FEED RATES FOR FLASH-TYPE DISTILLING PLANT

Distiller Rated Capacity	Citric Acid Feed Rates (gph) for Various Seawater Temperatures						
(Gallons per Day)	85°F	75°F	65°F	55°F	45°F	35°F	28°F
4,000	2.2	2.0	1.9	1.8	1.7	1.5	1.4
6,000	3.4	3.2	2.9	2.7	2.6	2.4	2.2
8,000	4.4	4.1	3.8	3.5	3.3	3.1	2.9
12,000	6.7	6.2	5.8	5.4	5.0	4.5	4.4
16,000	9.0	8.4	7.8	7.2	6.8	6.3	5.9
20,000	11.2	10.4	9.6	9.0	8.4	7.8	7.4
30,000	16.8	15.6	14.5	13.4	12.6	11.8	11.1
40,000	19.6	18.2	16.9	15.7	14.7	13.7	12.9
50,000	28.0	26.0	24.0	22.4	21.0	19.6	18.5
70,000	39.2	36.5	33.7	31.4	29.4	27.4	25.9
90,000	50.4	46.9	43.0	40.3	37.8	35.3	33.3
100,000	56.0	52.1	48.8	44.8	42.0	39.2	37.0

531-C.6 FILLING AND MIXING INSTRUCTIONS

531-C.6.1 The procedure for mixing the cleaning solution and filling the mixing tank is as follows:

1. Close valve V1 (Figure 531-C-1), and ensure that the mixing tank is clean before mixing the citric acid solution.

2. Determine the amount of citric acid cleaning solution required (Table 531-C-1 or Table 531-C-2). Never mix more cleaning solution than is required for 4 hours of cleaning. Fifty pounds of citric acid mixed with 8.5 gallons of water will provide 12.5 gallons of cleaning solution. If more solution is needed, mix in the same proportion.

3. Add the required amount of hot water (over 120° F) to the mixing tank.

NOTE

Always use hot water for mixing citric acid solution.

4. Add 1 pint of scale preventive compound for each 5 gallons of citric acid solution.

CAUTION

Incomplete mixing will cause the citric acid to cake, which may clog piping.

5. Slowly add citric acid to the mixing tank, stirring continuously. Continue stirring for 5 minutes after chemical has been added to ensure that the citric acid is completely dissolved. The solution will be clear when mixing has been completed.

CAUTION

To prevent cavitation of seawater feed pump or vapor locking of chemical feed pump, never allow tank level to fall below the suction connection.

6. If additional cleaning is required, repeat steps 2, 3, 4, and 5 when treatment tank level falls below 5 gallons.
7. For cleaning large distillers where more than 30 gallons per hour of citric acid solution are required (Table 531-C-1 or Table 531-C-2), two mixing tanks may be used with a tee and isolation valves to transfer feed from tank to tank (Figure 531-C-1).

531-C.7 CLEANING PROCEDURE

531-C.7.1 The procedure for preparing the citric acid cleaning system is as follows:

1. Prepare the citric acid cleaning system as described starting with paragraph 531-C.2.
2. Ensure that the steam supply pressure to the distilling plant critical flow orifice is as specified in the manufacturer's technical manual.
3. With both normal chemical treatment and citric acid cleaning systems secure, place the distilling plant in operation according to prescribed Engineering Operational Sequencing System (EOSS) procedures. For ships not having EOSS, follow the applicable technical manual. Maintain the design feed temperature and steam supply pressure. Record the initial values on the distilling plant log.
4. Chemical addition:
   a. Open valves V1 and V2 of the injection system, and verify the flow rate by monitoring tank level changes with respect to time.
   b. If the vacuum-drag method of injection is used for flash-type distillers, slowly close the distiller feed pump suction valve until 2 inches Hg vacuum appears on the feed pump suction gage. Adjust the seawater feed control valve to maintain the design feed temperature, and open the vacuum-drag control valves to obtain the chemical feed rate shown in Table 531-C-2.
   c. If the vacuum-drag method of chemical injection is used for submerged-tube or basket-type distillers, adjust the vacuum-drag control valves to obtain the chemical feed rate specified in Table 531-C-1.

NOTE

Citric acid reacts with distiller scale to form carbon dioxide. This reaction may cause carryover (priming), which is indicated by increased distillate salinity. Verify by chemical test.

d. If carryover is occurring, add 1 pint of distiller feed treatment to each 5 gallons of citric acid solution and reduce the citric acid feed rate as required to eliminate carryover. As the cleaning progresses and scale is removed, the citric acid feed rate can be increased without carryover. Increase the citric acid feed rate each hour as much as possible without causing carryover until the injection rate specified in Table 531-C-1 or Table 531-C-2 is reached.

5. If the distiller being cleaned is excessively scaled or is not mechanically sound (that is, has leaking condenser tubes, damaged demisters, etc.) distillate quality may not be within limits. When this occurs, continue cleaning but dump the distillate until sample analysis indicates it is within limits. Distillate quality that does not return to limits after 3 hours of cleaning indicates mechanical problems in the distiller that require repair.

6. Continue cleaning until the distiller operating parameters return to normal or until the cleaning has been conducted for a maximum of 8 hours.

7. When full distiller capacity and feedheater, first-effect tube nest, or basket vacuum have been restored, continue feeding until remaining solution in the treatment tank has been depleted. Secure the cleaning equipment and resume normal operation.

NOTE

Do not leave citric acid solution in the chemical addition tank. Neutralize and flush to bilge (see paragraph 531-D.1.4, step 13, for neutralizing instructions).

8. Disconnect the temporary vacuum feed treatment system. Flush and rinse it with freshwater (to the bilge), and store it for future use.

9. Record the total amount of citric acid used in the remarks section of the distiller log.

531-C.8 POSTCLEANING INSPECTION

531-C.8.1 If the distiller is not restored to design conditions after 8 hours of cleaning, perform a postcleaning inspection as soon as practical. If scale is present, obtain a sample of the scale and determine its solubility in citric and sulfamic acid as described in paragraph 531-C.1.3.

APPENDIX D.

SULFAMIC ACID CLEANING PROCEDURE

531-D.1 ALL PLANTS

531-D.1.1 REQUIRED EQUIPMENT. The following equipment and materials are required for cleaning distilling plants with the sulfamic acid method:

a. Relatively clean seawater (most harbor water is satisfactory) or an adequate supply of freshwater.

b. Vent hose. A 3/4-inch hose will be required to extend the air ejector vents to the weather deck.

c. Pipe and fittings. The number, location, lengths, and size of pipe required may be determined by comparing the ship's piping arrangement with Figure 531-D-1, Figure 531-D-2, or Figure 531-D-3. Plugs or caps should be obtained for fittings in the distilling plant system. Using hose for circulating acid, except when very long runs of pipe would be required, is not recommended since experience has indicated that using pipe is much safer and simpler.

d. Cleaning chemicals:
   1. Sulfamic acid, generally supplied in 100-pound drums with polyethylene bag liners, NSN 9Q 6850-00-637-6142.
   2. Sodium carbonate (soda ash), supplied in (100-pound paper bags), NSN 9Q 6810-00-233-1715

e. Safety equipment:
   1. Approved dust respirators for use when handling the dry acid
   2. Safety clothing. Rubber aprons and gloves are recommended. In their absence, wear foul weather gear.
   3. Safety goggles
   4. Safety hats
   5. Rubber boots. Trouser legs should be outside of boot tops.
   6. Signs: **DANGER ACID** and **NO SMOKING**
   7. Auxiliary mechanical ventilation
   8. Respiratory protective devices available on a standby basis.

531-D.1.2 SAFETY PROCEDURES. The following safety procedures apply to sulfamic acid cleaning of all low-pressure distillers, including submerged-tube, vertical-basket, and flash-type plants.

531-D.1.2.1 Dry Materials. Fiberboard containers of dry sulfamic acid powder and sodium carbonate should be stored and handled with the same care as are fiberboard containers of other materials. The dry powder will irritate the skin. If the powder contacts the skin or clothing, flush off with water. The dust of this acid will irritate the nose and eyes.

531-D.1.2.2 Handling. Dusting of the material should be avoided as far as possible by careful handling. Wear goggles and approved dust respirators. Sodium carbonate (soda ash) is also irritating to the eyes, mouth, and nasal passages. Dusting of this material should be avoided as far as possible. Wear goggles.

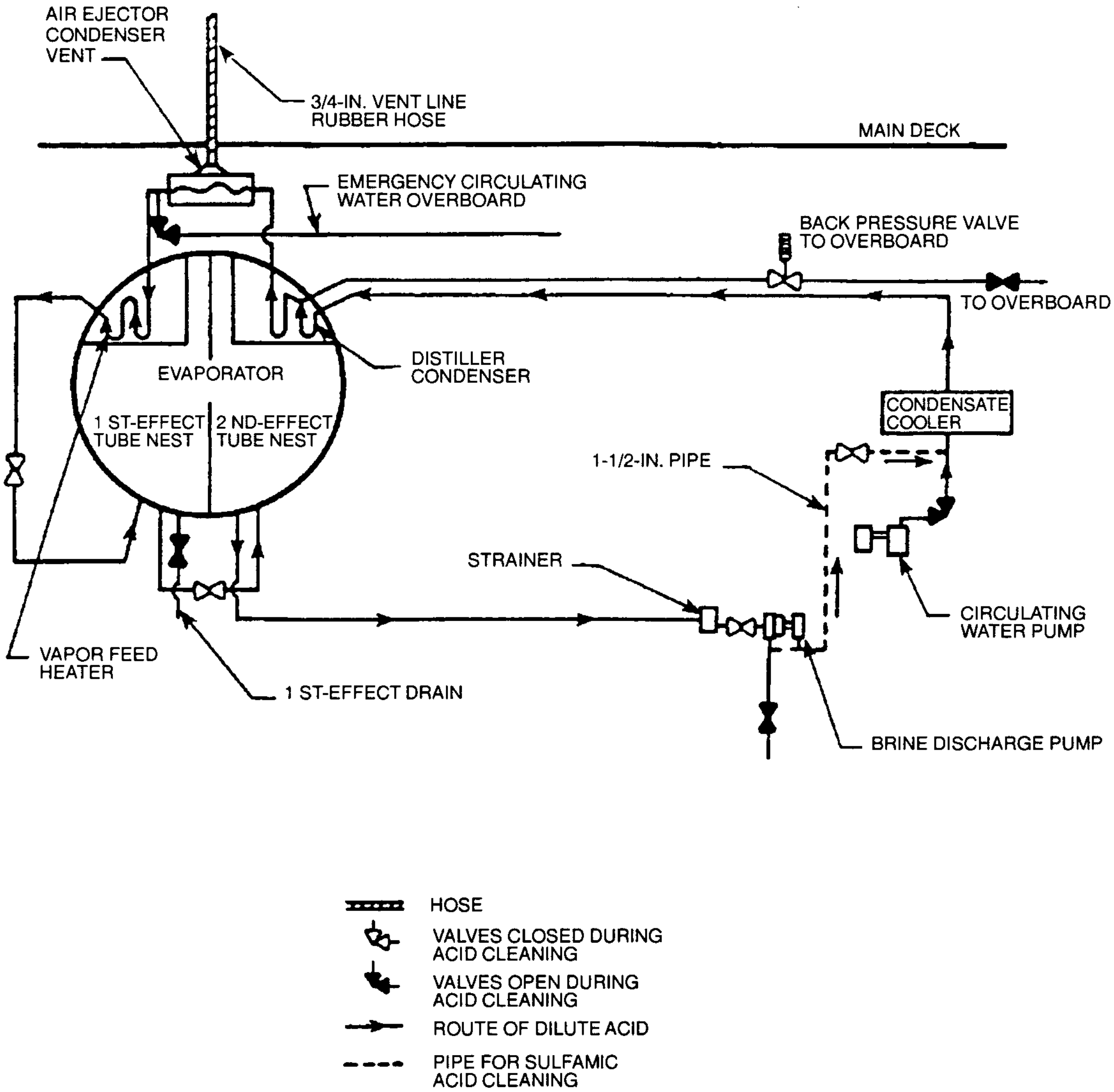


Figure 531-D-1 Piping Arrangement for Sulfamic Acid Cleaning of Solo-Shell Low-Pressure Distilling Plants

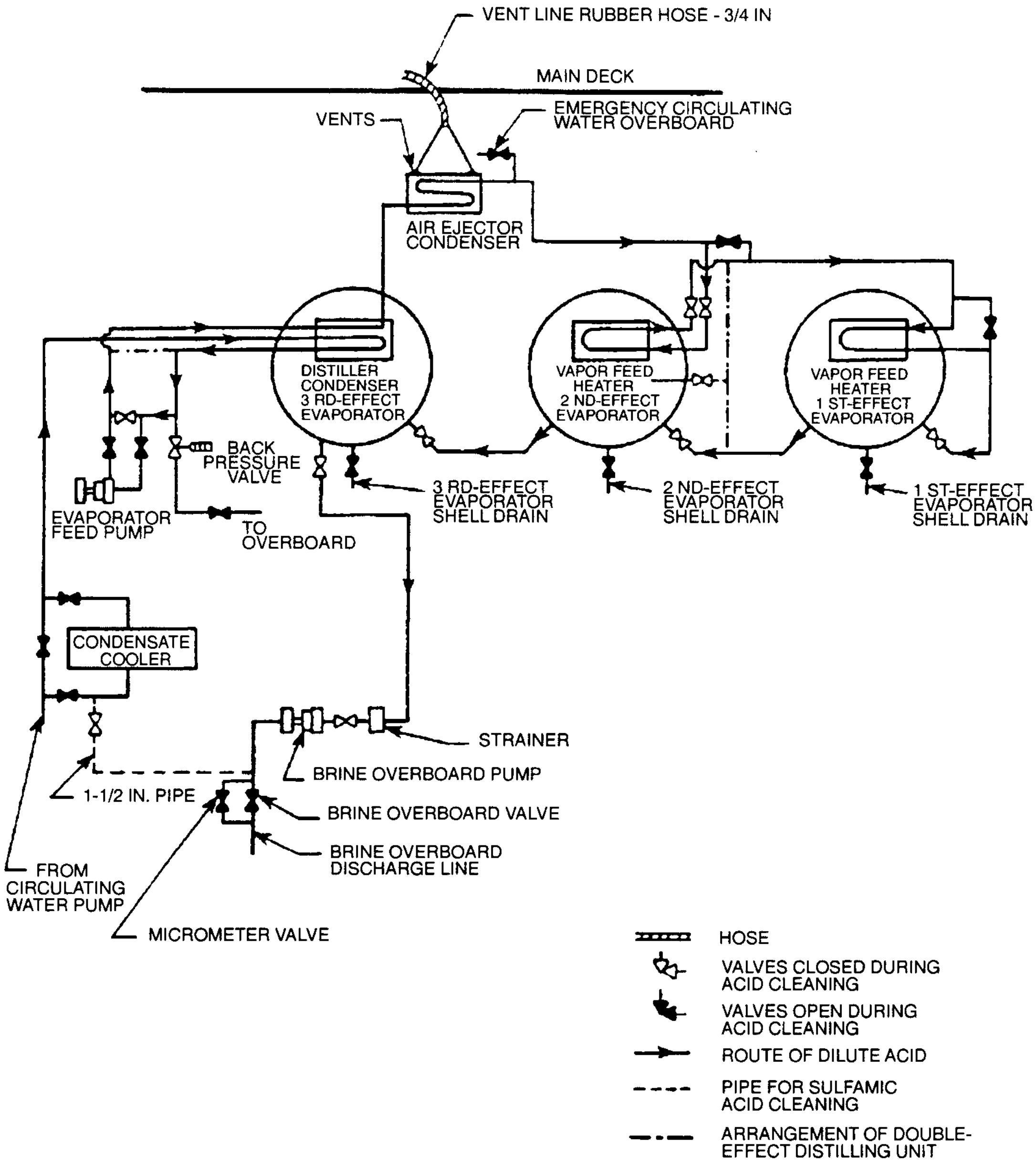
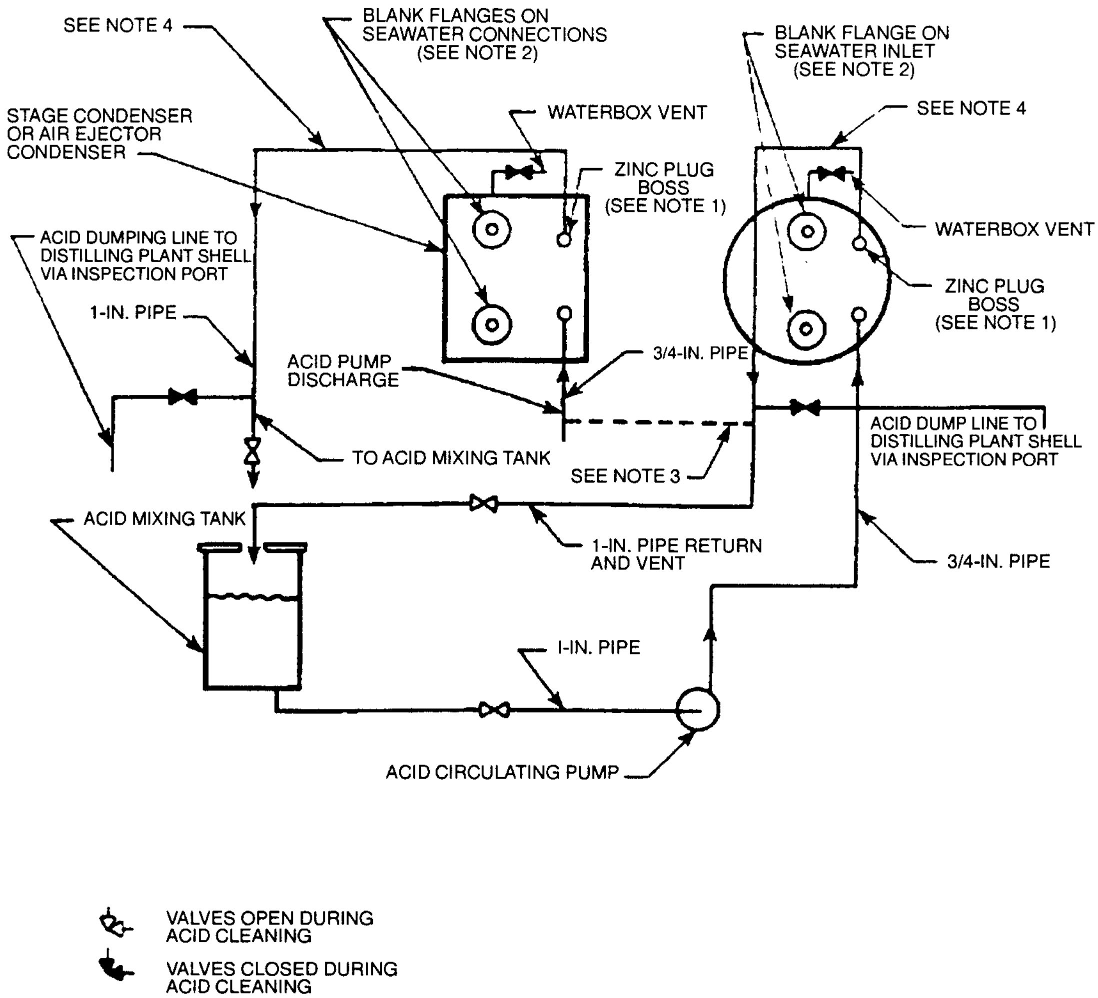


Figure 531-D-2 Piping Arrangement for Sulfamic Acid Cleaning of Double- and Triple-Effect Low-Pressure Distilling Plants



NOTES

1. When using zinc plug bosses, be sure all passes in heat exchanger are included in the circuit.
2. Blank flanges can be drilled and tapped for acid circulating pipe if zinc plug bosses cannot be used.
3. The two heat exchangers can be connected in series if both require cleaning.
4. Loop return pipe to ensure filling of heat exchanger.

Figure 531-D-3 Piping Arrangement for Sulfamic Acid Cleaning of Heat Exchangers on Flash-Type Distilling Plants

531-D.1.2.3 Sulfamic Acid

a. Properties. Although powdered sulfamic acid presents little hazard, in solution it is strong. The inhibited form is mildly corrosive to metals and somewhat irritating to the skin. Hydrogen may be released when the acid reacts with certain metals. To reduce the possibility of a fire or explosion, smoking, welding, and open flames shall be prohibited in the immediate vicinity of the distilling unit being cleaned or near the vent openings. Carbon dioxide (CO_2) is released in relatively large quantities during the cleaning process. Adequate ventilation shall be provided.

b. Treatment. If the dry powder or solution contacts the skin or clothing, flush off thoroughly with plenty of water. If the powder or solution gets into the eyes, wash out immediately and repeatedly with water, and report to sick bay immediately. If swallowed, report to sick bay immediately. Use the safety equipment listed in paragraph 531-D.1.1 to avoid exposure.

531-D.1.2.4 Sodium Carbonate (Soda Ash)

a. Properties. Soda ash is a white, granular powder. It presents no fire hazard, but it can cause alkali burns of the skin and eyes. The effect is similar to that of lye, but less severe. If taken internally, nausea and vomiting, pain in the throat and stomach, weak pulse, pallor, and collapse result.

b. Treatment. In case of accidental contact, wash the eyes with water for at least 15 minutes and report to sick bay immediately. For skin contact, wash with water and report to sick bay immediately. If taken internally, drink plenty of water. Do not induce vomiting. Summon medical personnel at once. Keep the patient warm and quiet.

c. Handling. Prevent dusting as far as possible since this will irritate the eyes, mouth, and nasal passages. Wear goggles at all times. While short-term contact with dry skin generally does not cause irritation, gloves should be worn.

531-D.1.3 PREPARATION. Refer to Figure 531-D-1, Figure 531-D-2, and Figure 531-D-3 when performing the following procedure. Submerged-tube units are shown in Figure 531-D-1 and Figure 531-D-2, but the acid connection arrangements are the same for basket-type units. For detailed instructions concerning the cleaning of flash-type units, see Figure 531-D-3 and paragraph 531-D.2.

1. Determine the solubility of the scale in the acid by placing a piece of scale in a container of acid-water mixture. Prepare the test acid mixture by adding acid powder to hot (150° F) water in a ratio of 1 pound of acid to 16 pounds (2 gallons) of water (1/4 pound of acid in 1/2 gallon of water will dissolve somewhat less than 1/8 pound of scale). A1-gallon metal can or plastic pail may be used. Maintain the mixture at a temperature of about 150° F. Any scale that will react with the sulfamic acid cleaning method will be almost completely dissolved. Continuously stir the acid and scale sample during this test. If the scale sample is largely unaffected, as indicated by lack of gas bubbles from the scale while the color of the solution remains red, the cleaning method will be ineffective.

2. Inspect the tubes through the ports, and log their condition (extent of scale formation, etc.). Note the thickness of the scale on the first-effect division plate or the shell of the submerged-tube units. This will help determine the initial acid charge.

3. Check all valves, piping, and fittings in the system, and replace any item that appears to be faulty or inoperative. Give special attention to the brine overboard and other seawater valves. Make sure that all gasketed joints are tight.

4. Ensure that the brine overboard pump is operating correctly.
5. Drain all water from the evaporators. Carefully remove loose scale from the bottom of the shells through the cleanout openings. Removing this loose scale will reduce the time and quantity of acid required to clean the distilling unit.
6. The acid solution will attack zinc anodes. Remove the anodes before beginning the acid cleaning.
7. Using 1-1/2 inch ferrous or nonferrous pipe, temporarily connect the brine overboard pump discharge to the seawater circulating pump discharge line before the condensate cooler. Install a 1-1/2 inch valve in this line. If this pipe is to be left permanently in place, use pipe of the same material as that installed in the distilling plant seawater system.
8. Remove all salinity-indicator cells.
9. Attach the 3/4-inch vent hose to the air ejector vent, and lead the hose to the weather or other well-ventilated location. The hose shall be free of kinks and shall slope continuously upward without loops or sags that might trap liquids in the hose and prevent proper venting.
10. Post **NO SMOKING** and **DANGER ACID** signs.
11. Close all valves not in use, including the brine overboard discharge, air ejector condenser and distiller condenser overboard discharge, circulating pump sea suction, feed treatment injection, bypass valves, and all skin valves. If a feed pump is installed in addition to the circulating pump, open the feed pump bypass valves. Close the feed pump suction and discharge valves.
12. Open all distilling plant shell vents.
13. Near the distilling unit, place the proper quantity of dry sulfamic acid required for the plant being cleaned. In estimating this amount, allow 1 pound for each gallon in the distilling unit when at the operating level (Table 531-D-1).

Table 531-D-1 SUBMERGED-TUBE AND BASKET-TYPE DISTILLING PLANT OPERATING LEVELS

Rated Capacity of Evaporator (Gallons per Day)	Approximate Operating Level (Gallons)
Double-Effect Evaporators (Including Solo-Shell)	
4,000	161
8,000	265
12,000	359
20,000	593
Triple-Effect Evaporators	
20,000	745
30,000	1055
40,000	1810
50,000	1900
Note This table applies to submerged-tube and basket-type plants only. For flash-type plant operating levels, refer to paragraph 531-D.2.3	

14. Open the valves in the circulating pump suction and discharge lines. Be sure that all evaporator shell vents

are open. Start the pump and fill the unit to the top of the evaporator tube nests of submerged-tube units, to the brine overflow outlets of vertical-basket-type units, or to the top of the distribution boxes of flash-type units, as seen in observation ports or gage glasses. (Mark the gage glasses to indicate the water level 2/3 of the way up the tube nest in the submerged-tube plants. This level will be required later to determine the initial acid mixture level.) As soon as the required amount of water is in the shells, stop the pump and close the valves.

15. Start the brine pump. Circulate the water through the heat exchangers in the feed circuit, into the evaporators, and from the final effect or stage, through the brine circuit back to the pump. Check for leaking valves or connections. If no leaks are seen, a drop in water level, other than the initial drop caused by filling the system, indicates a leaking overboard valve.
16. If leaks are seen or an overboard leak is suspected, secure the pump and repair the leaks. Continue circulating the water for at least 1 hour to establish definitely that all leaks have been repaired.
17. Drain the water from the plant.

531-D.1.4 CLEANING PROCEDURE

1. A scale thickness of 1/8 inch on the first-effect side of the division plate between the first and second effect or on the first-effect evaporator shell indicates that 1/2 pound of acid per gallon of water (according to Table 531-D-1) should be used for the initial charge. Do not use acid charges of less than 1/4 pound per gallon or more than 1 pound per gallon.

WARNING

The cleaning process may generate hydrogen gas. Always ensure adequate ventilation. Do not allow open flames in the vicinity of the cleaning operation.

WARNING

Sulfamic acid can severely irritate the skin and eyes. Wear protective equipment. In case of contact, flush affected area with water and report to sick bay immediately. If swallowed, report to sick bay immediately.

WARNING

Do not attempt to observe the reaction through an open observation port. Acid could spatter through an open port. If observation of the process is necessary, clean the glass in the observation port for this purpose.

2. Pour sulfamic acid powder into the evaporator shell. Use a chute formed from sheet metal to pour the powder into the shell through an observation port or other convenient opening. (Do not attempt to remove the glass from the observation port. Always remove the entire port assembly.) Close opening before admitting water to the shell.

3. Open the suction and discharge valves of the distiller circulating pump. Start the pump and fill the shells to a level 2/3 of the way up the tube nest in submerged-tube plants, to the brine overflow in basket-type plants, or to the top of the distribution boxes in flash-type plants.
4. Secure the circulating pump, and close the valves in the circulating line.
5. Start the brine pump to circulate the solution through the plant. At the same time bleed steam into the first-effect heating section or the seawater heater, and heat the solution slowly to about 150° F. Do not exceed 170° F, as the effectiveness of the inhibitor will be reduced.

NOTE

The color indicator in the powder will color the cold solution light red. When the solution is heated, the color will change to deep red.

6. The acid solution will react with the scale to form carbon dioxide, causing foaming. This carbon dioxide may also contain some hydrogen, which forms when sulfamic acid reacts with metal. Ensure that the distilling unit compartment is well ventilated and that the vent hose leads these gases to the weather. As the scale is dissolved, consuming the acid, the solution color will change from red to orange to yellow. Yellow indicates that the initial acid charge has been dissipated. To determine the color of the acid mixture, draw a sample into a clean glass from a convenient heat exchanger waterbox vent in the acid circuit.
7. Keep the levels in the effects about the same. These levels can be controlled by the feed valves to the first effect and by the feed valves, when provided, between effects. In submerged-tube units the solution should cover the tubes but should not rise more than 6 inches above the tube bundle. In vertical-basket units the solution should reach the brine overflow connection, but should not rise more than halfway in the upper gage glass. In flash-type units the solution should cover the feed boxes, but should not rise more than 6 inches above the feed boxes. If the levels tend to exceed the maximum limits, open the brine overboard valve and dump the excess solution overboard.
8. Circulate the initial charge of acid until the color of the acid changes to yellow.
9. If descaling of the evaporator shell walls above the normal operating levels is desired, throttle the flow from the evaporator shell to raise the level as far as necessary for cleaning the wall.

CAUTION

Do not permit the acid solution to enter the vapor separators in submerged-tube distilling plants. Any acid that passes through the separators will enter the distillate system and be lost to the acid circulating system. If any acid-water mixture enters the distillate system, drain and flush the system carefully.

10. As the acid charge becomes depleted, as indicated by the color of the solution changing to yellow, add 1/2 of the initial charge of acid to the solution. To add the acid, transfer sufficient solution to the first effects by closing the feed valve between effects. This allows the sight glass to be removed in one of the last-effect shells. Do not allow the solution to overheat during this operation. Do not allow the acid solution to enter the vapor separators in the effects being filled. After adding acid, continue circulation as previously described.
11. Continue adding acid until the solution remains red or orange-red and gas generation ceases for 1 hour. The system should then be clean. The heating surface will be cleaned first. Allow time for cleaning the evaporator shell, pipes, and other components. Discharge the solution overboard through the brine overboard valve when the system is clean.

12. Open the brine overboard discharge valve, close the valve in the temporary cross-connection between the brine pump discharge and the circulating pump discharge before the distillate cooler, and line up and start the distilling plant circulating water pump. Circulate the seawater through the system and by way of the brine pump to overboard for about 15 minutes while maintaining operating water levels in the effects. Secure the seawater circulating pump, and dump the distilling plant, using the brine pump.

NOTE

Disposal of the acid solution generated from the cleaning must be in accordance with NSTM Chapter 593, Pollution Control.

WARNING

Sodium carbonate (soda ash) can cause alkali burns of the skin and eyes. Wear protective equipment. In case of contact, flush skin with water, flush eyes for at least 15 minutes. Report to sick bay immediately. If swallowed, drink plenty of water. Do not induce vomiting. Summon medical personnel immediately.

13. Neutralize the system by circulating a 1-percent solution of soda ash (approximately 8.5 pounds per 100 gallons of water) or boiler compound (made by adding the neutralizing powder in the same manner as the acid powder) for 15 minutes. Follow by flushing with water.

14. Traces of acid left after dumping may turn the flushing or neutralizing water yellow. Flush the system until all yellow disappears. Disposal of the neutralized acid solution generated from the cleaning must be in accordance with **NSTM Chapter 593, Pollution Control.**

15. Drain the evaporators and secure the brine pump. Remove and stow the special pipe and fittings.

16. Renew or replace all zinc anodes.

17. Wash the tubes and shell interior with a water jet from a hose inserted through the inspection ports to remove any insoluble slime that may remain.

18. Renew the brine pump packing, and replace any leaking gaskets in the system. If replacing a gasket is impractical, repair the leak with a gasket-forming compound as described in paragraph 531-2.4.11.

19. Clean and reinstall all salinity cells. Follow the cleaning procedure as outlined in the salinity system technical manual.

20. Operate the distilling plant as soon as possible after neutralizing the acid in the system. Operate the plant for at least 1/2 hour after the salinity indicator (and chemical checks of distillate purity) indicate that the distillate is satisfactory for use.

21. Log and describe any leaks that develop after the acid cleaning. Also log the quantity of acid powder used initially and for recharging.

NOTE

It is impossible to circulate less acid-water mixture by throttling the flow from the evaporator shell and thereby causing the liquid level in the shell to rise. In this case, one effect is cleaned at a time and the cleaning period is somewhat longer.

NOTE

Some heavy deposits of calcium sulfate scale cannot be removed by sulfamic acid. In such cases, clean the distilling plant mechanically.

531-D.2 FLASH-TYPE PLANTS

531-D.2.1 SPECIAL CONSIDERATIONS. Descaling of flash-type units should be required only in the seawater heater and the heat exchanger, immediately upstream from the seawater heater in the saltwater circuit. In some designs this heat exchanger is the preheater; in other designs it is the air ejector condenser. The first- and second-stage condensers may also require descaling (less frequently than the seawater heater).

531-D.2.1.1 Large volumes of cleaning solutions would be required if the complete saltwater circuits, including all stage condensers, the flash chambers, and the brine lines were to be included in the cleaning cycle. To avoid this, each component requiring descaling should be cleaned individually.

531-D.2.2 REQUIRED EQUIPMENT. The following equipment is required for sulfamic acid cleaning of flash-type plants:

a. Chemical Mixing Tank. A metal container with a valved bottom outlet and a steam heating coil will be required. A 55-gallon oil drum will be satisfactory. This tank should have a removable cover with a hole in its center. This cover may be made from wood or metal. Acid powder will be added through the center hole to prevent splashing of the acid. If the tank is to be used repeatedly, as might be required by a repair ship or shipyard, an acid-resistant coating should be applied to the surfaces of the tank or the tank should be made from an acid-resistant material.

b. Acid Pump. A commercial centrifugal pump will be required. This pump shall be of acid-resistant construction and have the capacity to discharge approximately 10 gallons per minute of 170° F dilute acid solution against a static head of 20 feet. Because of its pumping characteristics, do not use a positive-displacement-type pump unless an adequate relief valve is installed in the pump discharge. Anticipate small pieces of scale clogging the system during the cleaning cycle.

c. Ventilation Equipment. The compartment in which the cleaning is done shall be well ventilated. Install extra ventilation equipment if any doubt exists about the adequacy of the compartment ventilation system.

d. Pipe and Fittings. Ferrous or nonferrous pipe can be used. Three-quarter-inch pipe is required to reach from the acid circulating pump discharge to the heat exchanger being cleaned. One-inch pipe is required to reach from the heat exchanger to the acid mixing tank to the circulating pump suction. Install valves in this piping in the acid circulating pump suction and in the return line. Blank the seawater connections with blank flanges on heat exchangers that cannot otherwise be isolated from the system. The feed control valve in the seawater outlet of the distilling plant seawater heater is a throttling valve operating in hot seawater. This valve will probably accumulate enough scale and erode sufficiently to prevent its being shut absolutely tight, especially when in contact with the acid. The seawater outlet of this heater should therefore be blanked. Do not use a hose for circulating acid. Experience has shown that using pipe is much safer and simpler (Figure 531-D-3).

e. Safety equipment. See paragraph 531-D.1.1.

f. Cleaning chemicals. See paragraph 531-D.1.1.

g. Safety precautions. See paragraph 531-D.1.2.

531-D.2.3 PREPARATION. Refer to Figure 531-D-3 when performing the following procedure:

1. Drain water from the system so that piping connections to the component to be cleaned can be broken.

2. Make sure that gasketed joints associated with the component are tight.

3. Inspect the tubes of the component to be cleaned by removing a waterbox or piping connections, and log their condition. Remove a scale sample, and test its solubility in sulfamic acid as directed in paragraph 531-D.1.3.

4. Replace all zinc pencils in the component with acid-resistant plugs (original zinc support plugs may be used.)

5. Connect the bottom outlet of the acid tank to the suction side of the acid pump using 1-inch iron pipe size (IPS) pipe.

6. For the saltwater heater:

   a. Connect the discharge side of the acid pump to a low point on the inlet-outlet waterbox using 3/4-inch IPS pipe. A zinc plug can be removed, and the pipe can be screwed into the zinc plug boss in the waterbox.

   b. Remove the feed outlet pipes to the saltwater heater, and blank these connections.

   c. Run a 1-inch IPS pipe to the mixing tank from a zinc plug boss at a high point in the inlet-outlet waterbox or a tapped hole in the blank flange. The pipe should terminate 4 to 6 inches below the top of the mixing tank. Place a tee in this line and run another pipe (with a valve) from this tee through an inspection port or other opening into a flash chamber. This line will be used to dump the system. (When removing the inspection port, do not remove the glass. Always remove the entire port assembly, if possible.)

WARNING

The gases generated during cleaning consist of carbon dioxide and some hydrogen. Be sure that these gases are vented to the weather. Allow no open flames in the vicinity of the cleaning operation.

   d. Arrange the mixing tank and return pipe so that carbon dioxide and hydrogen gas (generated during cleaning) will be vented through the return pipe.

7. For the preheater, the air ejector condenser, or the stage condensers:

   a. Remove the inlet and outlet feed piping, and replace with blank flanges. This may require removal of adjacent waterboxes on stage condensers in some designs.

   b. Connect with 3/4-inch IPS pipe the discharge side of the acid pump to a low point on the inlet-outlet waterbox of the heat exchanger.

   c. Connect a 1-inch IPS pipe to a high point on the inlet-outlet waterbox of the heat exchanger and run this pipe back to the mixing tank. Place a tee in this line, and run another pipe (with a valve) from the tee through an inspection port or other opening into a flash chamber. This line will be used to dump the system. (When removing the inspection port, do not remove just the glass. Always remove the entire port assembly, if possible.)

   d. Arrange the mixing tank and the return pipe so that the gases generated during the cleaning process will be vented through the return pipe.

CAUTION

The gases generated by this reaction consist of carbon dioxide and some hydrogen. A positive means must be used to ensure venting of these gases to the weather. Allow no open flames in the vicinity of the cleaning operation.

WARNING

Sulfamic acid can severely irritate the skin and eyes. Wear protective equipment. In case of contact, flush affected area with water and report to sick bay immediately. If swallowed, report to sick bay immediately.

8. Place near the mixing tank the amount of dry sulfamic acid required. To estimate this quantity in pounds, multiply the volume of the item being cleaned (in gallons of liquid) by 2.7. This liquid volume can be accurately determined by measuring the quantity of water initially required to fill the system. Record the volume for future reference.

531-D.2.4 CLEANING PROCEDURE. Clean flash-type distilling plants according to the following procedure:

1. Fill the mixing tank about 1/2 full of fresh water or clean seawater.
2. Start the acid pump and circulate the water through the heat exchanger. Add water until the tank is 1/2 full. Check for and correct any leaking connections. A drop in level in the mixing tank after the system is full indicates a leak in the system. Repair any leak before proceeding.

WARNING

Sulfamic acid can severely irritate the skin and eyes. Wear protective equipment. In case of contact, flush affected area with water and report to sick bay immediately. If swallowed, report to sick bay immediately.

3. While the water is circulating, slowly pour sulfamic acid powder into the mixing tank through the hole in the tank lid. Use 1/2 pound of powder to 1 gallon of water in the system.
4. Heat the solution slowly to about 150° F. If a seawater heater is in the circuit, this can be done by bleeding steam into the heater. If a seawater heater is not in the circuit, a steam coil in the mixing tank can provided heat. Do not exceed 170° F as the effectiveness of the inhibitor will be reduced.

NOTE

The color indicator in the powder will turn the cold solution light red. When the solution is heated, the color will change to deep red. The color of the solution can be determined by taking samples from the mixing tank or heat exchanger waterbox vent.

5. Continue circulating the solution, maintaining the temperature at 150° F.
6. As the scale is dissolved and the acid consumed, the solution color will change from red to orange to yel-

low. When the solution turns to yellow, add 1/2 of the initial acid charge. Continue adding 1/2 the initial acid charge each time the color of the solution turns yellow. Be sure (by using waterbox vents) that the heat exchanger is completely full of acid.

7. When the solution color remains red or orange-red and gas generation ceases for 1/2 hour, the system component should be clean.
8. Flush the system, open the valve in the 1-inch acid pipe that was run to the distilling plant shell by way of an inspection port, and close the valve in the discharge to the acid mixing tank. Add seawater or freshwater to the acid mixing tank at a rate equal to the capacity of the acid pump. Empty the distilling plant as often as necessary to prevent flooding. Continue circulation in this way for about 5 minutes.

WARNING

Sodium carbonate (soda ash) can cause alkali burns of the skin and eyes. Wear protective equipment. In case of contact, flush skin with water, flush eyes for at least 15 minutes. Report to sick bay immediately. If swallowed, drink plenty of water. Do not induce vomiting. Summon medical personnel immediately.

9. Neutralize the system by circulating a 1-percent solution of soda ash (approximately 8.5 pounds per 100 gallons of water) or boiler compound (made by adding the neutralizing powder in the same manner as the acid powder) for 15 minutes. Follow by flushing with clean seawater or freshwater as described above.
10. Traces of acid left after dumping may turn the flushing or neutralizing water yellow. Flush the circuit with clean seawater until all yellow disappears.

CAUTION

The acid solution is corrosive. Do not dump acid to the bilge.

11. Drain the circuit and stow all special fittings and pipes. Cap any permanently installed special fittings. Replace zinc anodes and restore the system to normal service.
12. Take care to flush any ships piping used for carrying this waste acid. Carefully flush bilges, floor plates, and any areas where acid may have spilled.
13. Replace all piping removed for the chemical cleaning operation. Open all valves in the feed and brine systems. Start the feed and brine pumps, and circulate seawater through the system so that the heat exchangers and evaporator shell will be thoroughly flushed out.
14. Replace any leaking gaskets. If replacing a gasket is impractical, repair the leak with a gasket-forming compound in accordance with paragraph 531-2.4.11.
15. Log and describe any leaks that develop after acid cleaning.
16. Operate the distilling plant as soon as possible after neutralizing the acid in the system. Operate the plant for at least 1/2 hour after the salinity indicator (and chemical checks of distillate purity) indicate that the distillate is satisfactory for use.

REAR SECTION

NOTE

TECHNICAL MANUAL DEFICIENCY/EVALUATION EVALUATION REPORT (TMDER) Forms can be found at the bottom of the CD list of books. Click on the TMDER form to display the form.