merely connected with the system of exhaust pipes which lead into the chimney casing and the military masts. The various cells for the confinement of prisoners are traversed by the ventilating pipes intended as supplies for the ammunition storerooms. The air escapes into the cells through small apertures in these pipes and leaves the cells through openings in the bulk-heads.

The forward station for the wounded has one, the after station two fresh-air inlets with cowls, while the foul air escapes through separate outlets. Most of the officers' cabins are dependent for their air supply on perflation, and this must be considered an important flaw in the whole system. All three of the above-named vessels are also provided with steam ash ejectors, which contribute largely toward keeping the ship's air clear of finely divided particles of inorganic matter.

5. *U. S. Training Ship "Prairie."*—We will conclude the chapter on ventilation with a description of the *Prairie's* system of ventilation, giving at the same time the results of some investigations into the working efficiency of the latter. The present training-ship *Prairie* is the converted steamer *El Sol* of the Morgan Line Steamship Company. She has a length of 404 feet over all and a beam of 44 feet; she has a gross tonnage of 6,782 tons, and is provided with a single screw, driven by a vertical, inverted three-cylinder triple-expansion engine of the ordinary marine pattern for commercial use, built at the Cramps' shipyard in 1890, and last commissioned at the Boston navy yard on November 9th, 1901; she has a spar deck, a gun deck, and a berth deck with the usual holds and storerooms below.

Since the berth-deck compartments are the only ones which have artificial ventilation, all her other compartments depending upon ventilation by perflation, the former will be the only ones included in the following description. The berth deck of the *Prairie* is divided by the large engine- and fireroom hatch into a forward and an after section of nearly equal dimensions, and between them there is no communication, the two iron bulkheads of the hatch reaching clear across from one side of the ship to the other.

The forward section of the berth deck is again divided by two cross bulkheads into three compartments with two communicating doors, symmetrically placed on each side of the two dividing bulkheads. The most forward of the three compartments is used for sick-quarters, the one next to this comprises the petty officers' quarters, and the third gives berthing space to a large number of men.

The after-section of the berth deck is likewise divided into three compartments, the most forward of which accommodates the dynamos, the next gives berthing space to the marine guard, and the last is for the chief petty officers.

There are three large square and three small oblong and rather narrow hatches in her decks, all superimposed and therefore well intended to send both light and air directly down into the deeper parts of the ship. The two electric fans of 110 volts each are both on the gun deck, just fore and abaft the fire- and engine-room hatches respectively. Each of the two large ventilating trunks, after passing through the gun deck, bifurcates, and the two branch trunks with their inlets run along the sides of the various compartments which they traverse, at a height above the berth-deck flooring of six or seven feet.

The two tables, showing the results of the anemometrical observations, are intended to exhibit at the same time in a diagrammatic manner the relative position of the different compartments, their cubic capacity, the number of inlets, and also the relative distance of the inlets from the fans or blowers. As may be seen in the columns of "cubic feet exhausted per hour," the amounts of air taken up by the different inlets decrease very rapidly and directly with their distance from the blowers. Inasmuch as the observations on the inlets and outlets rarely agree exactly, the largest figure is always taken as indicating the true value of the amount of work done by the fans.

TABLE X.—ANEMOMETRICAL OBSERVATIONS ON THE VENTILATION OF THE BERTH-DECK COMPARTMENT, MADE ON U. S. S. *Prairie*, AT SEA, ON JANUARY 5TH BETWEEN THE HOURS OF 1 AND 3 A.M. NUMBER OF INLETS TWENTY-SIX, WITH AN AVERAGE SQUARE AREA OF 0.4 FEET.

I. Forward of engine- and firerooms; average difference in number of turns of anemometer between the inlets is eighty-five per minute.

Number inlets, port.	Cubic feet exhausted per hour.	Bow.	Cubic feet exhausted per hour.	Number inlets, starboard.	Sum.
13	15,900	Sick-quarters, cubic air space, 4,700 feet, exhausted 22 times per hour; available air per head and per hour, 5,370 cubic feet.	15,900	13	
12	17,880		17,880	12	
11	19,920		19,920	11	107,400
10	21,960	Forward berth deck, cubic air space, 10,209 feet, exhausted 23 times per hour; available air per head and per hour, 2,674 cubic feet.	21,960	10	
9	24,060		24,060	9	
8	26,100		26,100	8	
7	28,140		28,140	7	200,520
6	30,120	Main berth deck, cubic space, 25,604 cubic feet, exhausted 16.5 times per hour; available air per head and per hour, 1,726 cubic feet.	30,120	6	
5	32,160		32,160	5	
4	34,260		34,260	4	
3	36,300		36,300	3	
2	38,280		38,280	2	
1	40,320		40,320	1	422,880
		Blower.	Grand	total,	730,800

II. Berth-deck compartments abaft the engine- and firerooms; average difference in number of turns of anemometer between the inlets is thirty-eight per minute; decreasing in a direction from the blower.

Number inlets, port.	Cubic feet exhausted per hour.	Blower. ↑		Cubic feet exhausted per hour.	Number inlets, starboard.	Sum.
1	33,780	Dynamo.		33,780	1	
2	32,880			32,880	2	133,320
3	31,980	Marines' quarters, cubic air space, 9,827 feet, exhausted 30 times per hour; available air for breathing purposes per hour and per head, 4,875 cubic feet.		31,980	3	
4	31,080			31,080	4	
5	30,120			30,120	5	
6	29,220			29,220	6	
7	28,320			28,320	7	301,440
8	27,420	Chief petty officers' quarters, cubic air space, 10,209 feet, exhausted 25 times per hour; available air per head and per hour, 3,430 cubic feet.		27,420	8	
9	26,520			26,520	9	
10	25,800			25,800	10	
11	24,900			24,900	11	
12	24,000			24,000	12	257,280
13	23,100	Closets.	Pantry.	23,100	13	46,200
14	22,200	Stores.	Stores.	22,200	14	44,400
		Stern.		Grand	total,	782,640

The after berth-deck compartments of the *Prairie*, by reason of their relatively smaller cubic capacity, are much better ventilated than the forward compartments, both fans doing about the same amount of ventilating work. The blowers are run at night only.

The tests for the amount of atmospheric carbon dioxide, exhibited in Tables XI. and XII., were made according to the method of Fitz, as modified by Woodman and Richards and described in the preceding pages. In making these examinations, it was the intention to get, as nearly as that was possible under the circumstances, a true and absolutely fair estimate of the amount of carbon dioxide present in the atmosphere of the different parts of the ship. None of the dark places in which the air naturally stagnates, such as storerooms and holds, and where the carbon dioxide was found up to 22 to 40 parts in 10,000, were included in these observations. The tests shown in the tables represent the compartments that are included in the general circulation of the area ventilated by the blowers. The results show what the carbon-dioxide content of the ship's atmosphere available for breathing purposes may be expected to be, when the ship is at sea and is sailing under the *most favorable* conditions of weather and climate. The influence of hatches, whether open or closed, of gunports, of the direction of the winds and of the blowers upon the carbonic-acid content, may be seen in the tables and studied in connection with the column of remarks.

As the blowers operate on the vacuum principle, it must, of course, be expected that the air, when it reaches the breather, is at its worst. The differences between the night and day averages in series I. were rather large, as compared with those shown in series II. The colder climate at Hampton Roads made it necessary for the comfort of the men sleeping below to keep the hatches covered and the ports closed. Under such conditions the vacuum system of ventilation shows its weak points. The fans arranged in accordance with the plenum principle would easily remedy these defects and convert a very faulty system of ventilation into an efficient one.

TABLE XI.—CARBON-DIOXIDE* OBSERVATIONS, SERIES I., U. S. S. *Prairie*, HAMPTON ROADS, VA., DECEMBER 27TH TO 28TH. SHIP HEADING N.E. BY E. AND W.S.W. RESPECTIVELY. WIND N.E., STRENGTH 2. ATMOSPHERIC TEMPERATURE DURING PERIOD OF OBSERVATIONS VARIED FROM 39° TO 45° F. WEATHER PARTLY MISTY AND PARTLY CLOUDY.

Time of day.	Sick-quarters.	Forward B. D.	Main B. D.	After B. D.	Warrant Off.	Forward G. D.	Remarks.
9 P.M	10.0	8.5	10.0	12.0	14.0	10.0	Hatches partly covered.
11:30 P.M.....	10.0	6.5	9.0	9.0	9.0	7.5	Blowers started at 12 midnight.
1 A.M	8.4	4.3	5.5	6.2	6.0	5.0	Blowers stopped at 5:30 A.M.
6 A.M	9.0	6.0	7.2	8.2	5.5	7.2	Gun-deck ports closed.
10:30 A.M	8.6	6.2	4.1	6.0	5.5	3.1	Gun-deck ports open.
11:30 A.M	7.5	3.5	3.0	4.0	4.0	3.0	Gun-deck ports open.
1 P.M	5.0	3.2	4.5	4.0	3.4	3.0	
7 P.M	7.5	4.0	10.0	4.2	4.6	14.0	Raining; hatch covers on; hammocks.
Averages.							
General......	8.3	5.5	6.1	6.4	6.0	5.9	
Night........	9.5	6.7	8.3	8.0	7.8	8.7	
Day..........	7.0	4.3	3.9	4.7	4.3	3.0	
Difference ...	2.5	2.4	4.4	3.3	3.5	5.7	Difference between night and day, averages.

* Numbers in columns indicate amount of CO_2 contained in 10,000 parts of air.

TABLE XII.—CARBON-DIOXIDE OBSERVATIONS, SERIES II., U. S. S. *Prairie*, JANUARY 4TH TO 5TH. AT SEA BETWEEN LATITUDES 16° 13′ 30″ AND 15° 08′ N. AND LONGITUDES 64° 25′ AND 63° 40′ W. COURSE E. BY S. STRENGTH OF WIND 4. ATMOSPHERIC TEMPERATURE VARIED FROM 78° TO 81° F. SKY PARTLY BLUE, PARTLY CLOUDY.

Time of day.	Sick-quarters.	B. D. main.	B. D. aft C. P. O.	Warrant Off.	G. D. aft.	G. D. forward.	Remarks.
9 P.M.........	8.8	8.8	8.8	5.6	5.6	5.6	Wind forward, weather clear.
11 P.M	4.1	4.1	5.0	3.7	3.7	3.6	Wind athwartship; ports open.
1:30-2:30 A.M.	5.8	6.2	6.3	4.3	4.0	3.9	Blowers running half speed.
11 A.M........	4.3	7.0	8.2	5.0	3.7	3.6	No one occupying sick-quarters.
1:30-2:30 P.M.	4.8	4.8	5.5	4.4	3.6	3.6	All gun-deck ports open.
5 P.M	5.0	5.2	5.8	4.2	4.0	4.6	All gun-deck ports open.
Averages.							
General......	5.5	6.0	6.6	4.8	4.2	4.2	Influence of open gun-deck ports shown; tends to lessen the difference between the night and day averages.
Night........	6.2	6.5	6.5	4.4	4.4	4.4	
Day..........	3.7	5.6	6.5	4.4	3.7	3.9	
Difference ...	2.5	.9	.0	0.0	.7	.5	

In concluding the chapter on ventilation we would emphasize two leading and important factors influencing a ship's ventilation, namely: (1) The plenum system of ventilation for ship's purposes is unqualifiedly recommended. (2) That the high atmospheric temperatures and humidities prevailing in warm climates, together with the prominent part played by physical heat regulation on the part of the men, make it possible that the air in ships may be renewed from fifteen to twenty times per hour, without danger from draughts.

II. WATER.

Every living organism, every single microscopic cell of this organism, has its normal amount of water under which alone it can perform its proper function, and the slightest departure from this normal percentage amount of water peculiar to its composition begins to initiate the series of changes that can have but one ending, namely, the death of the organism. The human body has in its composition sixty-five per cent. of water, of which it loses 2,500 gm. daily. As it receives from 500 to 800 gm. in the food, the remaining loss must be made good by drink. In experimental animals death inevitably ensues whenever the loss of water amounts to from twenty to twenty-five per cent. Those of us who live in temperate climates, in which water is found everywhere in sufficient quantity to supply our daily needs, hardly ever think of the possibility of dying of thirst; but those who live in the tropics know well how pressing and dangerous thirst can become as compared to hunger. As a means of personal cleanliness, it has become well recognized that it is economy to be lavish with the water supply, especially among soldiers and sailors, who must be so trained that cleanliness of person becomes to them a necessity and a habit.

With regard to the water-supply of ships, the last fifty years have brought about great changes. The general introduction of steam has made not only the voyages shorter, but it has been the means of making ships almost entirely independent of the shore as regards their water-supply. In times of wooden ships and long passages across the seas under sail alone, the water question was one of most serious concern to all seafaring men. Besides this, the generally prevalent lack of knowledge at that time of the importance of cleanliness in collecting, storing, and distributing the water on board ship was the cause of untold misery and long suffering, due to poor water and to the separation from a base of supply. The water was carelessly collected and then stored in tanks or barrels down in the dark holds of the ship. Often neither the water nor the barrels were examined, and consequently they left much to be desired as regards cleanliness. After a time the water began to emit a disagreeable odor, the essence of which was sulphureted hydrogen. This gas was produced by the decomposition of the sulphates in the water. In the course of time this gas was reoxidized and the disagreeable odor disappeared. This periodical reduction of the sulphates and oxidation of sulphureted hydrogen recurred several times during a voyage, and it was a common saying among sailors that the water had to putrefy three times before it became potable.

It certainly was true that the water did cease fermenting after a time, and consequently it was often better at the end of a voyage than at the beginning. We now are perfectly well acquainted with the causes of this fermentation and make use of this very property of water to purify it before filtration. It is the septic-tank method which has been found so effective in removing a large percentage amount of germs and fermentable organic matter, and which makes subsequent sand filtration so much more effective in producing a pure and potable water than it would be without it.

Although most of the naval vessels are supplied with distillers for the production of drinking-water from sea-water, it cannot be said that all ships of the navy are absolutely independent of water supplies from natural sources on shore. Circumstances arise on every naval vessel, and arise often, under which the water tanks are filled with water coming from shore. Naval sanitarians can, therefore, not yet afford entirely to disregard the hygiene of water supplies as found in nature.

The question of the water supply to naval vessels would, accordingly, resolve itself into (1) the supply from natural sources, and (2) the supply through distillation from sea water.

1. SUPPLY FROM NATURE'S RESERVOIRS. (*a*) *Rain Water.*—The quantity of water which a cubic kilometre of air is able to take up, when saturated at a temperature of 15° C. (60° F.), is no less than 15,990,000 litres. In the tropics the atmosphere covering a square mile of surface, at a temperature of 30° C. (85° F.), takes up two and a half millions of cubic metres of water. This water is driven by the wind to the different parts of the world, and returns to the earth in the form of rain, snow, or hail. The water, when it evaporates, is pure; but when it returns to the earth in the form of meteoric water it shows various forms of contamination, having absorbed not only the gases of the air, but carrying down also more substantial impurities with it. It is easily seen that rain water must differ in character with the quality of the atmosphere through which it falls; it must differ with the season of the year, and whether it falls in town or country. As rain purifies the air by taking down dust and smoke, it must become purer the later it is collected.

Of the water which is thus returned to the earth by precipitation, a small portion evaporates again immediately; the greater portion sinks to certain depths from the surface, becoming what is known as surface water; while still another portion runs off into rivers, brooks, and lakes, and the rest returns by way of the rivers and streams to the great sea whence it came.

In its passage through the atmosphere, it takes up, in the first place, a certain volume of air. The oxygen of the air being more easily soluble in water than is nitrogen, the air dissolved in water is richer in oxygen than the atmospheric air. Besides oxygen, rain water absorbs carbon dioxide, ammonia, and nitric acid. The farther above the surface of the earth rain water is collected, the more nitric acid it contains; and the nearer to the earth's surface it is collected, the more ammonia is found in it. The reason for this is that the ammonia emanating from the soil is gradually oxidized into nitric acid as it rises into the higher regions of the atmosphere. Thus 1 litre of water contains: Ammonia at 7 metres, 5.94 mgm.; at 47 metres, 2 mgm. Nitric acid at 7 metres, 5.68 mgm.; at 47 metres, 7.36 mgm. Rain water contains from seven thousand to twenty thousand bacteria in 1 c.c., which explains why it undergoes rapid fermentation on standing. Bujwid, who examined a hailstone 6 cm. long and 3 cm. thick, found twenty-one thousand bacteria in 1 c.c. of melted ice. Fontin, at St. Petersburg, discovered in a hailstone a coccus that proved pathogenic to mice.

Schmelch, in examining some ice from high mountains, in high latitudes, where organic life is not abundant, found but two microbes in a cubic centimetre of ice from Iostedlasbrü in Norway. Rain water is a soft water and very good for washing purposes; when used for drinking purposes, the first portions of it should always be rejected.

(*b*) *Surface Water.*—The term surface water is applied to the water contained in rivers, brooks, and ponds, into which the earth's surface is drained, especially after heavy rains. The composition of such water is influenced by local conditions, depending partly on the geological formation of the place, partly upon the character and amount of sewage washed into it and furnished by the towns in the vicinity. Epidemics of typhoid and cholera, traceable to infected river water, continue to recur with frequency, and these would be still more frequent than they are, were it not for the self-purification of river water and the nitrifying action of a certain class of saprophytic water bacteria. Such water, therefore, needs a thorough chemical and bacteriological examination before being taken on board, unless it comes from a place where sand filtration is used, and where all sewage is thus filtered before it is allowed to pass into the river, brook, or lake.

(*c*) *Ground Water.*—That portion of rain water which neither evaporates immediately nor flows off into rivers and brooks, but which gradually drizzles down into the deeper layers of the soil, until it strikes an impermeable layer of clay, upon which it accumulates, is known as ground water. As such it may feed a neighboring well or find its way to the surface again in the form of a spring. Borings often reveal the existence of several such subsoil lakes superimposed. The water, while drizzling through the permeable layers, gives up suspended matters, but takes up soluble ones instead, and hence its composition is essentially different from that of either rain or surface water. All those particulate impurities which rain water washes down from the atmosphere it loses in the uppermost layers of the permeable soil and before it becomes ground water; the organic matters are destroyed by oxidation, furnishing carbonic and nitric acids. Ground water, when obtained at a depth of 20 metres below the surface and well protected, has an agreeable taste and should possess a temperature representing the mean annual temperature of the place, which temperature is accepted as the most favorable temperature which a good drinking-water should possess. All the superfluous ground water finally flows off into subterranean rivers and lakes, which in turn are drained into the all-engulfing sea to start on a new round in its circulation. Such water is probably the best that can be obtained from natural sources.

In the royal navy of England and in the navy of the United States, the rule is that no water is to be taken or used on board until it has been examined and passed by the surgeon. In home ports, the water is either directly pumped on board from the city mains or it comes alongside the ship in a water boat. The latter method is usually bad and the water is often found contaminated, owing to leaky bottoms and leaky decks. No wooden water barge should be allowed to bring drinking-water on board a ship. In many foreign ports, recourse is had to fetching the water from shore by clearing the ship's boats of all removable gear and then filling them with water directly from the main; finally towing the boats back to the ship and pumping the water on board. All these methods are objectionable, because no boat is absolutely water-tight and sea water is bound to leak into it.

A time may come when it becomes necessary to take a battalion of men on shore and quarter them in a town for some time. Under such circumstances experience has shown the following rules to be worthy of adoption: (1) Let the men take their water from the same places from which the inhabitants draw theirs; these places should be plotted down by the officers arranging for quarters for the men. In case the water supply of the town is not free from suspicion, avoid taking water from wells in sloping streets and from those which are located in the neighborhood of poor dwellings, factories, dung-heaps, and avoid likewise, if you can, water flowing through the town; take it, if possible, from a point above the town. (2) Make provision against the contamination of the town water by the men themselves, who should be instructed in how best to avoid dangers from such a cause. (3) Mark the good wells from the bad ones. (4) Wells that have been out of use for some time must first be pumped out before they can be used again. (5) Contaminated wells must be placed under guard. (6) The too frequent and too copious use of a well is to be avoided because large draughts would cause a too rapid flow of the neighboring ground water in the direction of the well, through the subsoil, which might seriously interfere with the filtering capacity of such a soil, resulting in drawing impurities in with it. (7) In the case of wells, small rivers, and brooks, dams can be built in several places, of which the highest may be used for drinking purposes for the men, the lower for the animals and for cleansing purposes. (8) In case of rivers and shallow lakes, small bridges and waterways should be constructed so as to enable the men to get their water farther away from the shore and prevent them from stirring up the sediment at the bottom, which may harbor pathogenic germs. (9) In case the water has been rendered turbid by heavy rains, small wells may be sunk near the river and the filtering action of the soil or sand be taken advantage of; such wells must be protected and covered over by boards. (10) If the soil permits, tubular wells may be bored.

In France, Pasteur filters have been most generally introduced into all barracks. The water runs through these filters under a pressure of 10 metres, and, in places where this pressure cannot be obtained by natural means, it is produced by artificial means.

The great danger to troops is, as we all know, typhoid fever. No army seems to escape a certain amount of it. The typhoid bacillus respects neither race nor climate and is practically ubiquitous. Extensive experiments are now under way in England and other parts of Europe on the subject of the possible chances of vaccinating soldiers against typhoid, cholera, plague, and other diseases. The mortality from typhoid among the English troops in South Africa has been so great as to induce some of the best English bacteriologists to engage in serious experimentation in that direction.

For the purpose of sterilizing a suspected water in the field, in the absence of means for boiling large quantities of it, the method of Schumburg is the best. He uses bromine to render the water germ-free and removes the bromine afterward by the addition of ammonia. The apparatus comes conveniently packed in a box with the chemicals ready for use, and in quantities weighed out so as to sterilize any given amount of water in five minutes.

2. SUPPLY THROUGH DISTILLATION FROM SEA WATER.—If rivers, brooks, and lakes are the drainage basins into which flows the surface water of certain small circumscribed geographical areas, the great oceans may be said to receive the combined drainage of all the continents of the globe. From a chemical viewpoint, perhaps one of the principal differences between ground water and sea water is found in the large percentage of salts that are contained in the latter. These salts perform an important function which it is well to keep in mind. They assist in the penetration of solar heat, which otherwise would act on the surface only; salts also retard evaporation. Sea water teems with living organisms which, but for the preserving action of the brine, would die, and the products of their decomposition would render a life at sea practically unbearable if not altogether impossible. The salts in sea water also are the efficient causes of some of its circulating currents. Those, for instance, from the Mediterranean into the Atlantic, according to Maury, owe their main strength to this agency. The freezing point of sea water is put down as 27.2° F. The specific gravities, according to location, are as follows: (1) North Atlantic, 1.02676; (2) South Atlantic, 1.02664; (3) North Pacific, 1.02658; (4) South Pacific, 1.02548.

The temperature of the sea water is higher than that of the ground water of the same region. It varies, of course, with the latitude and the depth, and is greatly influenced by the circulation of the various currents coming from different localities. The Atlantic is the coldest, the Indian Ocean the warmest.

TABLE XIII.

	Total solids.	Organic carbon.	Organic nitrogen.	Ammonia.	Nitrogen as nitrites and nitrates.	Total combined nitrogen.	Chlorine.	HARDNESS.	
								Total.	Fixed.
Hastings, two miles from shore......	3.955	0.291	0.135	0.005	0.013	0.152	2.050	698	646
Gulf of Paria......	....	....	....	.003	.027	....	1.350	580	

The composition of sea water has been found to vary somewhat in different places and at different depths. In the vicinity of the poles, the percentage amount of salts is somewhat less than at the equator, while in certain parts of the Mediterranean more salt is found than in the great oceans. The average composition of sea water is given in the preceding table from Notter, to which has been added an incomplete and partial analysis made of the water in the Gulf of Paria.

According to Hales, it was Jean Antoine Gadesden who, as early as 1516, proposed distillation as a means of rendering sea water potable, and in 1560 Sebastien de la Pallière, of Sicily, proposed to the Duke of Moedina Coeli, while the latter was besieged by the Turks, in a fortress in which the cisterns had run dry, to distil sea water. He succeeded in producing thirty-five barrels of potable water in twenty-four hours. In 1717 Gauthier made an unsuccessful attempt to introduce distillers on board ship. After him, Lind proposed to utilize the steam coming from cooking utensils and condense it by leading it through cold-water tanks. Three years later, Poissonier designed a distiller which was similar to that of Lind, but which again failed of adoption on account of its taking up too much room on board! Finally Irving designed a distiller for which he received a pension of £500 from the English Government. All this shows how much the necessity for an apparatus of this sort was felt. A rather long time, however, had yet to pass before distilling became as general and practicable as it is now. There is perhaps no seagoing man-of-war at the present day that is not provided with one or more of these distillers, of which there are a large number of patterns.

In the French navy the "Cousin," modified by Mouraille & Co., and the "Normandy," which latter has the evaporator and condenser united into one apparatus, are generally in use. A special refrigerator by Perroy and a condensor by Fraser are also in common use. In the English navy the "Normandy," "Kirkaldy and Caird," and "Raynor" are employed. In the Austrian navy the French distillers have been adopted. The United States Naval Standard Evaporator is made of several sizes, the largest of which possesses a productive capacity of ten thousand gallons of distilled water per diem. The general design is identical for all sizes. The apparatus consists of two parts, namely: (1) the evaporator and (2) the distiller, sometimes called the condenser. The evaporator consists in a hollow cylindrical shell, made of steel and placed horizontally. The lower half of this cylinder is partially or loosely occupied by tubes running lengthwise, and fixed in their position at either end to a pair of plates which permit of the tubes being removed for scaling in their entirety. The tubes are connected with the main boilers, from which steam is run into them generally at a pressure not exceeding forty pounds. The sea water intended for distillation fills that portion of the lower half of the cylinder which is outside the tubes, but not quite reaching the upper level of the highest tubes. It is indeed the intention that the tubes shall not be completely immersed in the salt water, the upper level of which is, on the contrary, maintained considerably below the top of the tubes. The customary pressure within the shell is about ten pounds. By the use of the valves, the density of the sea water is generally maintained at $\frac{4}{32}$. The tubes of the distiller are made of tinned copper or brass; the joints are soldered. Thus we see that the evaporation of the sea water is caused by the heat imparted to it through the steam in the pipes which the sea water surrounds. The steam itself does not mix with the sea water. The distiller or condenser is a cylinder, made of brass or iron in various sizes, placed vertically and fitted with straight tubes for circulating cooling water, which is made to enter at the bottom and discharge at the top. The steam to be condensed passes through the condenser in the inverse sense.

On vessels which are equipped with very large plants for distilling water, the apparatus is arranged differently from the above. The work of distilling is divided into two or three stages and the working efficiency of the plant is thereby correspondingly increased. Under this system, steam from the boilers is used to evaporate the water in the first set of evaporators; this evaporated steam is used to heat and evaporate the water contained in the second set of evaporators, and this in turn is made to evaporate the water contained in a third set. This last steam is finally condensed to water in a distiller of the above description. This system more than doubles the actual thermal efficiency of the distilling apparatus, but it is not installed except in very large ships, on account of the complications in mechanical fittings which it necessitates.

The precautions usually observed are as follows: (1) The plant is operated only when pure sea water is obtainable. (2) For drinking-water, the plant is not operated to its full capacity, in order to reduce priming or carrying salt water directly over into the distillate. (3) Tests of the complete plant are made daily to insure tightness of all the joints. (4) The water level in the evaporators is kept low. (5) When the ship is under way and rolling heavily, the plant is worked at its lowest capacity. (6) The pressure of the cooling water in the distiller is limited by departmental order to thirty pounds, which is to minimize the danger of salt water leaking into the distillate. (7) Tests of the distillate are made every fifteen minutes.

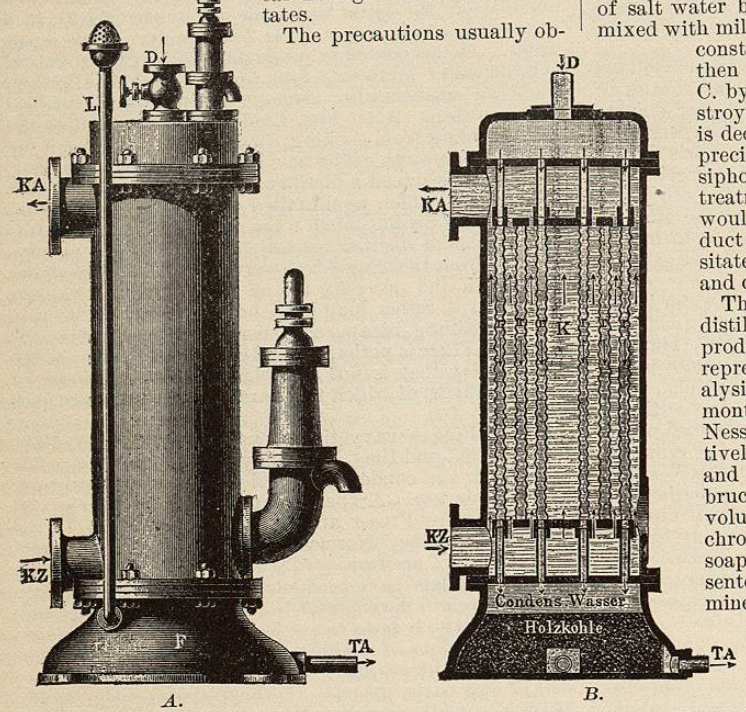

FIG. 3508.—(From Kirchner.) The Transatlantic liners of the North German Lloyd are equipped with distillers of the "Acme" patent. These were preferred on account of their combining great efficacy, small space and ease with which they can be handled and worked. The condenser is shown in the adjoining two figures *A* and *B*. The steam generated in an auxillary boiler is made to enter, at *D*, into the condenser, which consists of a vertical cylinder, 110 cm. long and 36 cm. in diameter. The steam now passes into a number of tubes, made of thin copper *r r*, outside of which a constant and rapid stream of cold sea water passes from below upward, entering at *KZ* and leaving the cooler at *KA*. The distilled water, at the lower end of the condenser, enters a charcoal filter, *F*, where it is purified, and, at the same time, aërated by the air coming in through the tube *L*, with which it is here in communication. The water, both filtered and aërated, is finally collected at *TA*. The apparatus furnishes 18 cubic metres of good potable water in twenty-four hours. The warships of the imperial German navy are all equipped with distillers made on the same principle as those of the "Acme" patent.

The process of distillation, however, always involves an expense which sometimes may be considerably greater than the price at which good drinking-water can be bought on shore, and then it becomes the duty of commanders of vessels to secure such water when of good quality and whenever practicable. Besides, the process of distilling is not always faultless and the product occasionally needs looking into.

Water Distilled from Sea Water.—Although the water obtained from sea water by distillation may not be absolutely pure, it has nevertheless stood the test of many years' practical experience, and hence must be considered to be harmless. The mineral salts, contained in sea water, sodium and magnesium chloride, lime, alkalies, acids, bromine, iodine, etc., especially magnesium chloride, in decomposing during the process of distillation, vitiate the product to a certain degree. In order to obviate these objectionable features, Rubner ("Lehrbuch d. Hygiene") proposes the following preliminary treatment of salt water before distilling: The salt water is to be mixed with milk of lime in special tanks and kept, being constantly stirred up, for fifteen minutes; it is then heated up to a temperature of about 60° C. by steam. All organic matter is thus destroyed and coagulated. Magnesium chloride is decomposed by the lime and the magnesia is precipitated. After all has settled the water is siphoned off and distilled. This preliminary treatment, if it could be carried out practically, would no doubt result in a more uniform product of distillation; it would, however, necessitate a reconstruction of all the evaporators and condensers at present in use.

That sea water under the present system of distillation does not furnish a uniformly pure product may be seen from Table XIV., which represents an almost daily though partial analysis of such water, continued for nearly a month. Free ammonia was determined with Nessler's reagent; the nitrites were qualitatively determined with the sulphanilic acid and naphthylamine test; the nitrates with brucine and sulphuric acid; chlorine with a volumetric solution of silver nitrate, potassium chromate as indicator; hardness with standard soap solution; and the organic matter, represented in milligrams of oxygen, was determined by a standard solution of potassium permanganate. All these solutions were made on board ship and according to the methods given in Harrington's excellent manual of "Practical Hygiene." The analyses show that the water produced in our distillers always contains quite appreciable quantities of chlorine, lime, and magnesium salts (represented by hardness), and also organic matter; less frequently ammonia, and still less frequently nitrites and nitrates. All these, in the above quantities, must be considered harmless. With few exceptions the water was free from odor and perfectly colorless.

An important point, to which it is necessary to call attention in connection with the chemical composition of water distilled on board ship, is the hygienic significance of it. It will be seen at once that we must judge this from a standard entirely different from the one in accordance with which we would judge a surface or a ground water. Ammonia, nitrites, nitrates, as also chlorides, when found in a properly collected sample of river or well water, would justly arouse great suspicion, while the same chemical compounds in the water distilled from sea water arouse no such suspicion. These stand simply for a certain amount of nitrogen in different stages of oxidation and are otherwise perfectly harmless in the quantities in which they appear. No living organism, neither an animal nor a vegetable parasite, capable of producing disease could possibly survive such a process of distillation.

The following table is interesting from quite another point of view; it shows that, while a small quantity of organic matter is constantly present in the distillate, ammonia, nitrates, and nitrites are almost as constantly absent. This would indicate an almost absolute absence of all oxidation during distillation. When, however, we consider that the salt water, from which our distillate is obtained, does not come directly from the sea, but has already been used as condense water and gone through the distiller in which it has been heated up to a high temperature, then this is easily explained. By the time such water arrives in the evaporator as feed water, all the air has been driven out.

TABLE XIV.—TABULATED RESULTS OF TWENTY-TWO ANALYSES OF WATER DISTILLED FROM SALT WATER BY THE UNITED STATES STANDARD EVAPORATOR.

U. S. S. *Prairie*, Gulf of Paria. January, 1902.	Free ammonia.	Nitrites.	Nitrates.	Chlorine, in milligrams per litre.	Hardness, in milligrams calcium chloride.	Organic matter, represented in milligrams of oxygen per litre.
3.	+	0	0	220	10.0	0.0
4.	0	0	0	30	5.0	2.0
5	+	0	0	20	4.0	3.5
6.	+ +	0	0	10	6.0	1.7
7.	+	0	0	50	11.0	3.6
8.	+ +	0	0	20	16.0	2.0
9.	+	0	0	24	7.0	3.2
10.	0	0	0	130	13.0	6.5
13.	+	0	0	8	4.0	2.0
14.	+	0	0	12	4.0	3.0
16.	+	0	0	20	5.5	3.0
17.	+	0	0	20	6.0	3.0
18.	+ +	+ +	+	160	10.0	4.0
20.	0	0	0	30	4.5	4.5
21.	0	0	0	30	5.0	5.0
22.	0	0	0	20	5.0	3.0
23.	0	+ +	0	90	10.0	2.5
25.	0	0	0	12	7.0	2.0
26.	0	0	0	20	8.0	3.0
27.	0	0	0	32	6.0	2.0
28.	0	0	0	80	8.0	120.0
30.	0	0	0	32	5.0	3.0

The Stowage and Distribution of Water on Board.—If, notwithstanding the fact that, as we have seen, no reasonable objections can be entertained from a sanitary point of view against the water distilled on board ship, complaints, and very pressing ones, are still often heard against the drinking-water supplied to officers and men, what are they due to? In almost every instance to unclean tanks and faulty pipe connections, as perhaps the following instance from my own experience will best serve to illustrate. It was not many days after our ship had been placed in commission and her officers and men had begun to live on board, that the presumably pure and distilled water was found absolutely non-potable and everybody refused to drink of it. The water was undoubtedly and indescribably bad. A sample of it was immediately collected from one of the spigots in the galley, under the usual precautions, and analyzed, with the following results:

November 26th, 1901, sample of water supposedly distilled:

1. *Color.*—Distinctly yellowish, very turbid, depositing on standing a brownish flocculent sediment.
2. *Odor.*—On being heated in a flask and shaken, a very perceptible, strong, musty odor is present.
3. *Residue.*—On evaporation grayish-white, turning black on being heated to redness.
4. *Free* as well as *albuminoid* ammonia present in large amounts, forming brownish precipitate.
5. *Nitrites.*—Positive reactions with the starch iodine test as well as with the sulphanilic acid and naphthylamine test.
6. *Chlorine.*—NaCl, 2.5 gm. per litre.
7. *Hardness.*—Equal to ninety parts of calcium chloride in ten thousand parts.
8. *Nitrates.*—Positive reaction with brucine.
9. *Lead.*—Grayish discoloration with hydrogen sulphide and acetic acid.
10. *Organic Matter.*—In abundance and not determined quantitatively.

Based upon the results of the above analysis, the probable source of contamination was put down as being dirty salt water from the harbor in which the ship was lying; also improperly cleaned tanks and pipes, as was made apparent by the water giving reactions for lead. When the result of this analysis and the inevitable conclusions it led to were communicated to the commanding officer, an immediate inspection of the entire water-supply system of the ship was made, and the source of the contamination quickly and decidedly traced to a very faulty system of pipe connection existing between the sweet and the salt water reservoirs on board. Owing to this connection, it was impossible to draw either sweet or salt water from any of the spigots without getting a mixture of both in varying proportions.

The bacteriological examination of a sample of this water, made at the Bacteriological Laboratory of the Harvard University College of Medicine, showed the presence of liquefying bacteria in large numbers, while that of a sample of water collected from the distiller proved absolutely sterile.

A more common source of lead in ship's drinking-water is found in the pipe joints, especially in newly made ones, of which several instances have recently come to our notice. The red lead used for the purpose of making joints water-tight should be forbidden and asbestos used instead, in all pipes used for water distribution. Early in the history of distilling water on board ship and the laying of pipes for its convenient distribution, A. Le Fèvre, of the French navy, discovered lead in the water; and quite recently Dr. Cautellauve (1891–92), also of the French navy, has again reported several cases of lead poisoning from the same cause, during his cruise in the East on board the *Troude*.

Time and space do not permit here to go into a detailed description of the various methods of modern water analysis. Nor is it necessary to mention the characters that a good drinking-water should possess. These are matters of general hygiene and can easily be found in every work on that subject. There is no doubt that the naval surgeon, equipped with a practical knowledge of the laboratory methods used in water analysis, will be well able to make such a selection of apparatus and reagents, before going to sea, as will enable him to make a very satisfactory water analysis, wherever and whenever called upon to do so. There may be some difficulties as regards accommodations on board some ships, but there are none that cannot be overcome. His difficulties certainly cannot be greater than are those of the army surgeon in the field.

The water-supply systems and the chemical composition of the water supplied by them, of every one of the islands near our coast, including all the Antilles, should be systematically investigated. The composition of every important well in common use and out of use on every island should be known, recorded, and plotted on geographical maps for immediate reference. With some encouragement and the necessary means and apparatus, this work could easily be done by naval medical officers.

III. THE RATION.

FOODS AND NUTRITION IN GENERAL.—While it cannot be expected, in the limited space allotted to this paper, that we enter at all into the special physiology of nutrition or into the chemistry of foods, it is, on the other hand, absolutely necessary and unavoidable briefly to touch upon those of the leading principles and methods according to which the nutritive values of those of the food substances in common use on board all sea-going vessels and included in the navy ration, are ordinarily determined.

Daily experience and observation have sufficiently acquainted us with the fact that the physical part of our existence consists in a perpetual and constant effort on the part of the living organism to adapt itself to an ever-changing series of outside conditions. In this supreme effort the organism uses up constantly part of its own organized substance, expending it as, or converting it