DEPARTMENT OF OCEANOGRAPHY
UNIVERSITY OF WASHINGTON

Technical Report No. 30

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Office of Naval Research
Contract N8onr-520/III
Project NR 083 012

Reference 54-14

July 1954

SEATTLE 5, WASHINGTON

UNIVERSITY OF WASHINGTON DEPARTMENT OF OCEANOGRAPHY
(Formerly Oceanographic Laboratories)
Seattle, Washington

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by

Thomas G. Thompson and Kurt H. Nelson

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R.H. Fleming

Richard H. Fleming
Executive Officer

Desalting Sea Water by Freezing

Removal of Salt from Sea Water by Freezing Produces a Potable Water and the Energy Needed for Refrigeration Is Far Less than Required for Distillation

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THE most obvious method for obtaining fresh water from the sea has been by distillation. Many different types of efficient stills have been designed. However, hot sea water and hot brines are exceedingly corrosive. Furthermore, upon heating, calcium and magnesium carbonate tend to precipitate and as the sea water is concentrated calcium sulfate likewise forms. Thus, to prevent incrustation by these salts, the hot brine must be discarded after 30 percent of water has been removed.

Very little attention has been given to the possibility of obtaining fresh water from sea water by refrigeration. A large number of patents have been issued for this purpose, but there is lack of fundamental data.

Various technical problems exist in connection with freezing, including separation of salts from the ice, design of heat transfer units for application during the melting of the ice, and design of the counterpart of the multiple-effect still.

A search of the literature revealed that data on the distribution of salts in sea ice are rather meager. Malmgren[6] reported that the salt content of ice produced under natural conditions depends upon the rate of freezing. The concentration of salts decreased with increasing depth below the surface of the ice, and also the salinity of the new ice increased as the air temperature decreased. Steinbach[8] recently reported results obtained by freezing solutions of artificial sea water containing only sodium chloride.

The use of sea ice as a source of fresh water has been known to the inhabitants of the Arctic regions since prehistoric times. Vessels plying Arctic waters in the summer months have often watered ship from ponds formed on ice floes by the melting ice.

The processes occurring during the freezing of sea water differ from those of fresh water. Since the temperature of maximum density of pure water is 39.2 F, cooling water below this temperature results in a decrease in the density of the water. The colder, less dense water floats over the more dense water. When sea salts are added to fresh water, the temperature of maximum density, as well as the freezing point, is lowered. For an increase of one part per thousand in salinity, the temperature of maximum density is lowered 0.387 deg F, while the freezing point is decreased only 0.097 deg F. Thus, for a water with a salinity of 24.70‰ (chlorinity 13.67‰), the freezing point and the temperature of maximum density are identical, 29.62 F (Thompson[10]). For sea waters of average salinity the temperatures of maximum density are below the freezing points. As sea water freezes, fresh water precipitates as crystals of ice. The density of the liquid phase immediately adjacent to the ice thus increases in density. This denser solution tends to sink and is replaced by water of lesser density. Brine remaining from sea water frozen in the laboratory collects mainly on the bottom of the vessel, rather than in the center of the ice cake, as in the freezing of fresh or slightly brackish water. The ice formed from sea water has a rather porous nature due to the entrapment of brine

Experimental

The investigations described below were undertaken to obtain quantitative information on the distribution of salts in ice formed by the freezing of sea water, to ascertain the salinity of waters obtained from the melting of such ice, and to examine the extent of any potable water produced.

In the first series of experiments, cylinders of ice, formed by freezing sea water at different air temperatures, were cut into a number of discs. Each disc was

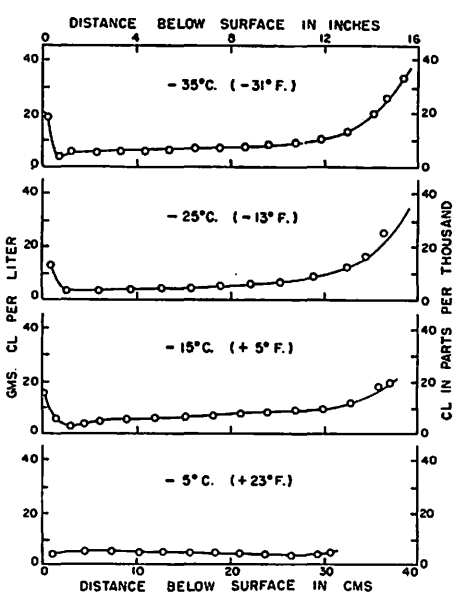

Fig. 1. Chloride concentration at various depths in ice formed at different temperatures.

This paper to be presented at the 41st Semiannual Meeting of American Society of Refrigerating Engineers in Seattle, Washington, July 11 to 14, 1954.

Reprinted from the July 1954 issue of REFRIGERATING ENGINEERING, official publication of the *American Society of Refrigerating Engineers*

allowed to melt and the chlorosity of the water obtained from each disc was determined.

For the second series of experiments, sea water was frozen at different air temperatures and the chlorosity of the water at various depths in the receptacle was determined after the ice had melted in situ.

The sea water in the third series was frozen at different air temperatures and the brine was drained from the ice. As the ice slowly melted, the water was collected in fractions and analyzed periodically. In the fourth series of experiments, the sea water was continually agitated during freezing at temperatures between 28 and 24.5 F.

The sea water used in the experiments was taken near the entrance to Puget Sound and had a chlorinity of 16.60 $^0/_{00}$ (salinity 30.00 $^0/_{00}$). The water was filtered through a sintered glass filter of F porosity before it was used.

The salt content of the water expressed as grams of chloride ion per liter at 68 F (chlorosity) was determined by the Mohr method using 0.01 and 0.1 N standard silver nitrate solutions and a few drops of a saturated potassium chromate solution as the indicator.

Salt Distribution in the Ice—Malmgren's observations in the distribution of salts in sea ice were made on ice formed under natural conditions. As ice forms in the sea, the resulting denser water sinks and is replaced by more water of the original density. When ice forms in a receptacle of sea water in the laboratory, the water in contact with the ice becomes increasingly concentrated. As it is difficult to duplicate the natural conditions, the distribution of salts in the ice formed under laboratory conditions was investigated in freezing cylinders of water at different air temperatures.

A refrigerator was constructed which permitted freezing samples of sea water from the surface downward. This effect was obtained by building cylindrically shaped wells in the freezing compartment into which the containers of sea water could be placed. The space between the inner wall of the well and the outside of the container was insulated to prevent immediate freezing around the walls of the container. A Frigidaire MM-3 compressor unit, employing Freon-12 and capable of maintaining temperatures from 23 to 45 F, with a variation of ±2 deg F, was incorporated into the apparatus. The entire unit, with exterior dimensions of 30 by 30 by 72 in., was portable.

A paraffined cardboard tube, 2½ by 18 in. high and sealed at the lower end with a rubber stopper, was filled with 1200 ml of sea water and placed vertically in the freezer. The sides of the tube were insulated with felt to promote freezing from the top surface. When freezing was completed, the tube was removed from the freezer and the brine was drained off by removing the rubber stopper. In all the experiments reported there was always a minute quantity of brine retained on the surface of the ice. This surface brine was removed and the ice was sliced into discs approximately 0.4 in. thick without permitting any melting of the ice. The chlorosity of the water from each disc was determined after the ice melted. The data are given in Table 1 and plotted in Figure 1 for tubes frozen at four different air temperatures.

There was a slight decrease in chloride concentration with depth for the ice cores formed at 23 F. The reverse condition was found to exist for the ice cores

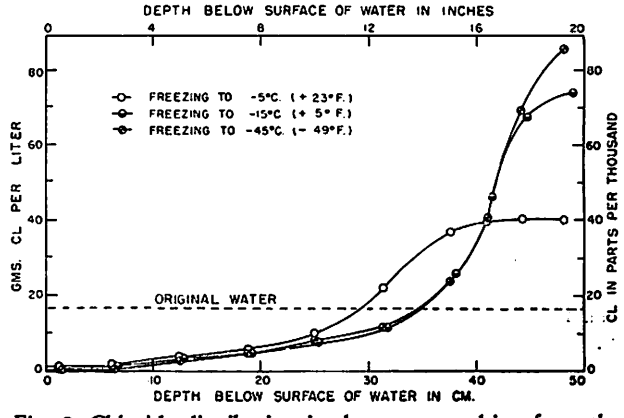

Fig. 2. Chloride distribution in the water resulting from the melting of ice in situ after freezing sea water at different temperatures.

frozen at the other temperatures. The effect of the brine retained on the surface of the ice is readily noticeable in the graphs of Figure 1.

As a general statement from the results of this series of experiments, it may be said that 20 to 25 percent of the total salts in the initial volume of water are occluded by the ice under laboratory conditions.

Should the ice be permitted to melt, the liquids first forming should contain most of the salts occluded by the ice. This denser solution would gravitate to the brine in the lower part of the container. To determine the stratification of the waters resulting from the melted ice, the following experiments were devised.

Salt Distribution in Waters after Ice Melted—The receptacles used for freezing the sea water were glass cylinders 7.87 in. diameter, 23.6 in. high, and had a capacity of more than 4.75 gallons.

After each sample of 3.96 gallons was frozen, the cylinders were removed from the freezer and the ice was allowed to melt without draining off the remaining brine. When the melting was completed, samples were pipetted at approximately 2.36 in. intervals beginning at the surface of the water. At about 4 in. from the bottom of the cylinder, samples were taken at 1.2 in. intervals.

Since convection currents would tend to occur during the melting and freezing processes, and particularly if melting was too rapid, the above experiments were first conducted at 5 F under different conditions whereby the rates of freezing and/or melting were altered by the use of insulation material around the

Table 1. Chloride Concentration at Various Depths in Ice Formed at Different Temperatures

23 F		5 F		—13 F		—31 F	
Distance below surface, in.	*Cl, parts per thous*	*Distance below surface, in.*	*Cl, parts per thous*	*Distance below surface, in.*	*Cl, parts per thous*	*Distance below surface, in.*	*Cl, parts per thous*
0.47	4.67	0.12	15.18	0.35	12.96	0.20	18.25
1.22	4.93	0.55	5.33	1.06	3.36	0.71	3.50
1.77	5.26	1.18	2.52	1.70	3.73	1.22	5.03
2.36	5.29	1.77	3.53	2.36	3.71	1.73	5.26
2.95	4.91	2.36	4.57	2.99	3.86	2.24	5.06
3.86	4.91	2.95	5.00	3.70	4.14	2.76	5.23
4.06	4.80	3.54	5.38	4.41	4.46	3.27	5.32
4.57	4.87	4.13	5.33	5.04	4.55	3.78	5.50
5.12	4.78	4.76	5.75	5.59	4.56	4.29	5.51
5.63	4.89	5.35	5.72	6.22	4.47	4.80	5.81
6.18	4.59	5.98	6.07	6.85	4.54	5.31	5.95
6.73	5.31	6.57	6.85	7.48	5.09	5.87	6.37
7.28	4.47	7.17	6.70	8.11	5.65	6.38	6.47
7.80	4.02	7.76	7.28	8.74	6.13	6.93	6.56
8.21	4.27	8.31	7.03	9.41	6.45	7.44	6.81
8.82	4.12	8.90	7.62	10.04	6.77	7.95	7.08
9.34	4.11	9.49	7.94	10.71	7.38	8.46	7.26
9.88	4.12	10.08	8.49	11.42	9.00	9.02	7.72
10.43	3.80	10.67	9.00	12.09	10.53	9.53	8.22
11.02	4.04	11.26	9.20	12.83	12.53	10.08	8.78
11.61	3.91	11.95	9.03	13.58	16.09	10.59	8.99
12.13	4.68	12.40	10.56	14.33	25.00	11.14	9.56
		12.99	11.50	15.12	48.64	11.69	10.29
		13.58	13.64			12.24	11.20
		14.13	17.97			12.80	13.36
		14.65	19.64			13.35	15.97
						13.90	19.79
						14.45	26.68
						15.16	33.28

cylinders. Except for a slight decrease in chloride concentration in the surface layer of the water which melted more slowly under insulated conditions, no noticeable difference was found between insulated and uninsulated conditions. The results were generally reproducible to within 5 to 10 percent.

Table 2 and Figure 2 give desalinification data produced by freezing samples to temperatures of 23, 5, and —49 F and then by melting of the ice at room temperature. In these experiments the containers were well insulated to insure slow freezing and melting. There was marked desalting of the water in the upper portions of the cylinders in all cases. The brine remaining at 23 F had a concentration considerably less than the brines obtained at lower temperatures, but occupied a much greater volume.

Removal of Salts from Melting Ice—Although the first experiments indicated that the ice had a high salt content, the first water from the slowly melting ice after removal of the brine would contain a very high percentage of the occluded salts and brine. The first ice

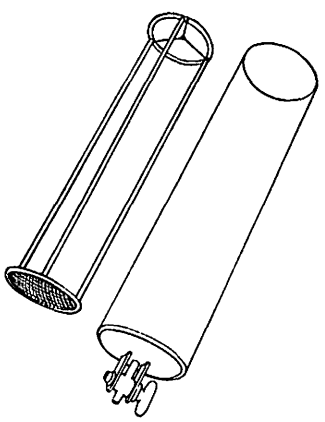

Fig. 3. Sketch of Lucite container and screen used for the continuous removal of water from melting ice.

to melt would be that immediately adjacent to the interstitial salts and brine retained in the ice. The resulting liquid, gravitating through the ice, would be of high salinity. The remaining ice would then have only exceedingly small fractions of the original salts. Water formed by the later melting of the residual ice would be

Table 2. Chloride Concentration of Samples Taken at Various Depths in Cylinders After Melting of Ice

Air temp of refrig	23 F		5 F		—49 F	
Total water above sampling point, gal	*Depth, in.*	*Cl, parts per thous*	*Depth, in.*	*Cl, parts per thous*	*Depth, in.*	*Cl, parts per thous*
0.10	0.43	0.90	0.51	0.44	0.43	0.52
.53	2.44	1.32	2.56	1.31	2.44	1.09
1.06	4.92	3.53	5.00	3.25	4.92	2.78
1.58	7.36	6.05	7.48	4.50	7.36	4.92
2.11	9.80	10.65	9.96	7.27	9.80	7.77
2.64	12.32	22.13	12.48	11.84	12.32	11.43
3.15	14.80	37.02	15.10	25.92	14.80	23.76
3.45	16.10	39.93	16.30	46.06	16.10	40.87
3.65	17.40	40.18	17.60	67.25	17.40	69.22
3.96	18.94	40.22	19.29	73.96	18.94	85.42

fresh water. To ascertain not only the extent of the removal of salts from the ice, but the quantities of fresh water formed, the following experiments were conducted. The sea water was frozen to the desired temperature and the residual brine was drained from the ice, which was then allowed to melt with the water being removed as it formed.

The apparatus consisted of a special container of Lucite and a Technicon fraction collector of the photoelectric drop counting type. The container was constructed by cementing a conical Lucite bottom to a Lucite pipe 4.82 in. diameter and 19.7 in. high. A short section of 0.24 in. diameter Lucite tubing was cemented in a hole of similar size in the center of the conical bottom. Drainage of the container was through a stopcock fastened to the Lucite tubing by rubber tubing. A Lucite screen of 0.24 in. mesh was attached to three Lucite rods and could be removed from the container. The screen and container are shown in Figure 3.

The container, filled with five liters of sea water, was placed in the freezer. A glass tube, 20 in. long and sealed at one end, was set in place in the container. This tube later provided an air inlet to facilitate the drainage of brine and water from the melting ice. When thermal equilibrium had been attained, the container

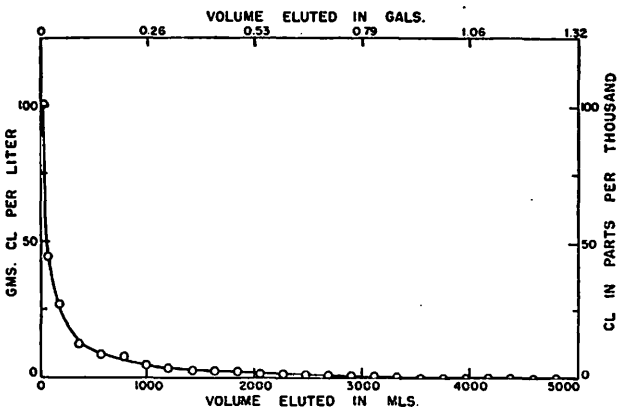

Fig. 4. Chloride concentration and volume of brines and waters obtained by melting and eluting sea water subjected to freezing at different temperatures.

was removed from the freezer and placed on the Technicon fraction collector. The sealed end of the long glass tube was broken off and the fraction collector was turned on. After a glass delivery tube had been attached, the stopcock was used to regulate the flow of brine from the container. When the brine had drained, the stopcock was fully opened. The volume of brine or water collected in each test tube (about 20 ml) was controlled by adjusting the fraction collector. The screen supporting the ice was raised sufficiently so that none of the ice would be suspended in the water resulting from its melting.

Chlorosity of the water in every tenth test tube was determined. The total volume of liquid collected up to each chloride determination was obtained by summation of the individual measured volumes of water in

Table 3. Volumes and Chloride Concentrations of Brines and Waters Obtained by Melting and Eluting of Sea Water Subjected to Freezing at Different Temperatures

23 F		5 F		—13 F		—49 F	
Volume eluted, ml	*Cl, gm/l*	*Volume eluted, ml*	*Cl, gm/l*	*Volume eluted, ml*	*Cl, gm/l*	*Volume eluted, ml*	*Cl, gm/l*
21.8	79.49	18.6	120.4	19.0	143.4	21.6	166.0
108.6	79.38	95.8	118.8	91.2	134.4	97.0	107.7
218.7	78.66	197.6	99.70	194.4	79.14	200.0	76.24
437.3	66.48	392.1	79.50	378.6	61.44	425.1	57.09
664.3	36.48	596.4	51.01	563.4	42.73	630.9	45.77
889.8	31.86	794.9	35.52	763.0	32.31	821.8	31.90
1115	28.40	997.9	26.70	955.1	23.86	994.2	25.29
1230	25.24	1233	18.79	1151	18.44	1222	17.46
1527	21.16	1438	14.48	1349	13.51	1422	13.06
1729	14.01	1609	12.03	1547	10.51	1629	10.79
1926	10.49	1818	8.91	1749	8.52	1850	9.13
2131	7.54	2046	4.16	1952	8.09	2066	6.13
2334	5.73	2280	2.75	2156	5.23	2275	4.98
2522	4.08	2516	1.72	2462	3.36	2487	2.84
2734	3.37	2776	1.19	2650	2.46	2710	1.97
2927	2.29	3074	0.74	2857	1.61	2921	1.65
3143	1.73	3264	0.43	3066	0.87	3133	0.81
3345	1.05	3496	0.28	3286	0.48	3352	0.57
3550	0.58	3708	0.17	3493	0.37	3592	0.18
3756	0.26	3938	0.08	3695	0.18	3828	0.11
3958	0.16	4185	0.02	3890	0.10	4054	0.04
4157	0.07	4447	0.01	4085	0.04	4277	0.02
4377	0.03	4633	0.01	4278	0.02	4497	0.006
4585	0.01	4833	0.002	4470	0.01	4716	0.003
4799	0.003	4930	0.002	4661	0.01	4932	0.006
				4849	0.02		

each test tube. The data are tabulated in Table 3 and shown graphically in Figure 4.

The water from the later portions of the melted ice had a very low salt content and contained less than the U. S. Public Health Service maximum of 500 ppm total dissolved solids for potable water. Table 4 gives the chloride concentrations in grams per liter (obtained from graphs of the data in Table 3 by means of a planimeter) for different fractional volumes of water from

Table 4. Chloride Concentration of Fractional Volumes of Water from Melted Ice and Residual Brine by Planimeter Determination and from Data Illustrated in Figure 4

Temp of freezing / *Fractional volume, liters*	*23 F* Cl, gm/l	*5 F* Cl, gm/l	*—13 F* Cl, gm/l	*—49 F* Cl, gm/l
0 to 1.0	55.06	65.40	57.65	59.74
1.0 to 3.5	10.70	6.85	6.44	6.97
1.0 to 5.0	7.14	4.05	4.00	4.20
1.5 to 5.0	4.00	1.99	2.38	2.42
2.0 to 5.0	2.37	0.84	1.31	1.32
3.0 to 5.0	0.44	0.17	0.21	0.23
3.5 to 5.0	0.13	0.07	0.07	0.06

the melting ice and the residual brine. These results represent the concentrations that would exist if the waters of the fractions indicated were homogenous. From an examination of these data the following conclusions may be drawn: (1) 80 percent of the total salts originally present in the five liters are confined to a volume of one liter, (2) 50 percent of the water was partially desalted and contained only 20 percent of the salts originally present in the sea water, and (3) 30 percent of the sea water, or 1.5 liters, has been sufficiently desalinified to yield a potable water containing from 70 to 130 ppm chloride, which is equivalent to 126 to 234 ppm total solids.

The yield of potable water could be increased considerably by reprocessing the partially desalted water. To simulate this partially desalted water, sea water was diluted to a chlorosity of 3.32 grams per liter. This diluted sea water was frozen at 5 F, the resulting ice was melted and analyzed in the same manner as above. The data obtained are given in Table 5 and are graphically presented in Figure 5.

Agitation of Water while Freezing—To ascertain the yield of ice and brine, 2.5 liters of sea water were placed in a 4-liter beaker fitted with an electric stirrer; the entire assemblage was placed in the freezer. Moderate continuous agitation during freezing produced a heterogeneous mixture of brine and ice particles with a diameter of 1 to 2 mm. However, when the temperature of the freezing mixture decreased below 25.7 F, marked difficulty was experienced in stirring due to the slushy nature of the mixture of ice and brine. Immediately before separating the brine and ice, the temperature of the mixture was measured to the nearest 0.09 deg F with a calibrated Western Electric 14B Thermistor and a Wheatstone bridge. The brine and ice were quickly separated in a large chilled Buchner funnel by means of suction. A sheet of thin rubber placed over the funnel was found advantageous in furthering the removal of the brine from the ice crystals. After the ice melted, the volumes of the resulting water and the brine were measured. The data are given in Table 6.

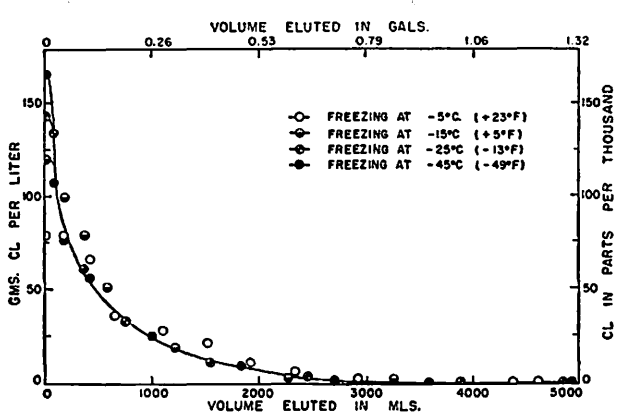

Fig. 5. Chloride concentration of brine and water obtained by reprocessing partially desalted water at 5 F.

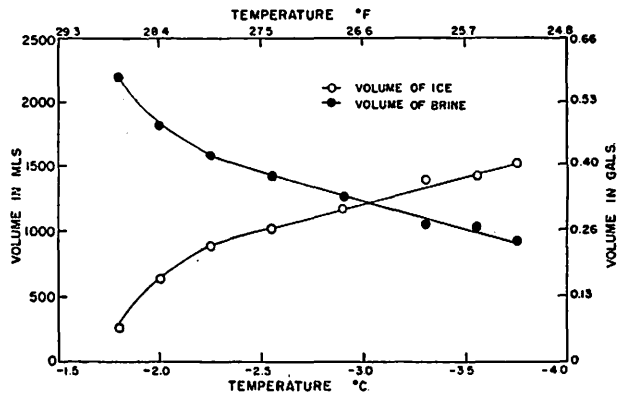

Fig. 6. Volumes of brine and ice in equilibrium at various temperatures when partial freezing of 2.5 liters of sea water occurred during agitation.

To study the effectiveness of removal of brine adhering to the ice, 2.5-liter samples of sea water were frozen as before. After the temperature of the mixture of brine and ice was measured, a sample of the brine was taken for analysis. Suction was then used to separate the ice from the remaining brine in a chilled Buchner funnel, approximately one-third of the ice being removed from the funnel for analysis. To demonstrate that much of the brine adhered to the ice surfaces, the remaining ice was washed once with 250 ml of chilled distilled water, sucked dry, and about half of the ice taken for analysis. The sheet of thin rubber aided the removal of the brine and the subsequent wash waters from the ice crystals. The ices were analyzed for chloride content after melting.

Table 5. Chloride Concentrations and Volumes of Brine and Water Obtained by Melting and Eluting of Partially Desalted Water Refrozen at 5 F

Volume eluted, ml	*Cl, gm/l*	*Volume eluted, ml*	*Cl, gm/l*
10.4	100.3	2272	1.23
76.4	44.52	2481	1.03
179.1	27.08	2688	0.94
368,2	12.22	2898	0.59
574.6	8.61	3114	0.42
788.8	7.49	3328	0.23
998.4	4.53	3541	0.14
1207	3.51	3752	0.08
1427	2.60	3963	0.04
1638	2.27	4174	0.02
1851	2.33	4383	0.01
2062	1.39	4591	0.008
		4797	0.002

Table 6. Volumes of Brine and Ice Obtained at Various Temperatures When Partial Freezing of 2.5 Liters of Sea Water Occurred During Agitation

Temp, F	*Volume of ice, ml*	*Volume of brine, ml*
28.8	258	2200
28.4	637	1820
28.0	888	1579
27.4	1019	1420
26.8	1178	1260
25.9	1397	1047
25.6	1427	1020
25.2	1521	919

Discussion

Distribution of Salts in Ice—Although the salts concentrate in the brine at the bottom of the vessel when

sea water is frozen in the laboratory, 20 to 25 percent of the salts are retained in the ice either as brine or deposited salts. The concentration of salts in the ice increases slightly with depth below the surface when the ice is formed at air temperatures below 23 F. The expected increase in salt content for the porous ice in contact with the bottom brine is found for all temperatures. In addition, a small amount of brine appears on the surface of the ice at lower temperatures.

Melting of Ice in Situ—When the ice melts in contact with the brine, the resulting water shows decided stratification because of density differences. Although the bulk of the salts is in the brine at the bottom, the upper waters contain a sizeable amount of the total salts due to convection currents and mixing during melting of the ice. The surface water is relatively fresh since it is formed from the last of the salt-free ice.

Drainage of Brine before Melting of Ice—If the brine is removed from the ice before the ice is permitted to melt, the first water drained from the melting ice possesses a high salinity due to the natural washing out of occluded salts and brine. The concentration of salts in the outflowing water constantly diminishes until the last 30 percent of the water is potable. The yield of fresh water can be increased to at least 50 percent by refreezing the partially desalted water.

Formation of Ice during Agitation—The temperatures used in this series of experiments were much higher than for the other experiments. An examination of the data shows that the amount of salt retained by the ice increased as the temperature of the mixture was lowered. The chloride concentration averaged about 4 parts per thousand of melted ice for temperatures above 25.7 F. Below this temperature, the amount of occluded salts increased materially as the process of agitation became more difficult. Since the high concentration of chloride was due mainly to brine adhering to the ice, the amount of chloride was reduced considerably by one washing.

By allowing ice to melt slowly with drainage of the resulting water, the occluded brine would be washed out by the first waters of the melting ice because of the lower melting point of ice particles immediately adjacent to occluded salts and brines, leaving essentially fresh ice.

When the temperature of the ice and brine mixture has decreased to 25.7 F, over 50 percent of the water in the original sea water has been transformed into ice. After losses from washing the ice and discarding the first waters from the melting ice, the yield of fresh water would be from 40 to 50 percent. Due to difficulties of agitation and because of the increase in the salt content of the ice at lower temperatures, the yield of potable water would be scarcely increased by lowering the temperature of the mixture below 25.7 F. The same ice particles formed during agitation are adaptable to large scale handling. Lowering the temperature to 21 F would transform about 80 percent of the original sea water into ice.

The fresh water obtained by the melting of ice formed by freezing sea water in the laboratory will not be entirely free of salts as would be the case if the water had been procured by distillation. However, if a comparison is made of the calculated energy requirements for getting equal quantities of fresh water by distillation and by freezing from the same amount of sea water of similar salinities, it will be found that a very considerable energy difference exists. While no data are available for the heat of vaporization or the specific heat of sea water at higher temperatures, it may be assumed that these are about the same as for pure water. Thus, according to calculations, approximately six times as much energy is required for distilling sea water as is needed to freeze it. This difference in the required energy will vary slightly depending upon the original temperature of the sea water being processed and the amount of fresh water to be recovered from a given quantity of sea water.

The use of sea ice as a source of fresh water has been known to inhabitants of the Arctic regions since prehistoric times. Vessels plying Arctic seas in the summer months have often watered ship from ponds formed on ice floes by the melting ice.

Several years ago Congress appropriated a considerable sum of money for the purpose of studying the recovery of fresh water from saline waters. A special office, the Saline Water Conversion Program, has been established under the Secretary of the Department of the Interior to consider the problem.

An annotated bibliography (Chapman and Lineweaver[2]) on producing fresh water from saline water has been compiled by this organization. Methods for the precipitation of the dissolved salts in sea water were developed during World War II in order to obtain small quantities of potable water during emergencies (Consolazio, et al[3]; Tiger, et al[11]). The use of solar energy as a means of producing fresh water has been investigated recently (Telkes[9]). A historical summary of the development of distillation, the usual method for the recovery of fresh water from sea water, has been published by Hampel[4]. Howe[5] has presented a survey of several methods for refining sea water, including compression distillation, multiple-effect distillation, solar distillation, the electrolytic process, ion exchange, freezing, and the thermal-difference power plant. Cost data, fuel requirements, and other factors for the various methods of sea water reclamation, except by freezing, have been given by Aultman[1]. The cost estimates published by different writers vary depending upon the fuel costs and unit efficiencies quoted. The cost of obtaining fresh water by freezing sea water has been estimated to compare favorably with compression distillation which has the best economy of any scheme for distillation.

Operations at low temperatures would reduce problems arising from the corrosive effects of sea water and resulting brines. The possibility of recovering salts from concentrated brines obtained by freezing sea water has been indicated by the authors in a paper now in press (Nelson and Thompson[7]).

There are many regions of the world faced with the problem of an inadequate or improper supply of fresh water and yet from these very regions one may gaze upon a vast expanse of ocean, the waters of which cannot be used for terrestrial purposes because of the dissolved salts.

The oceans cover 70 percent of the earth's surface and have an average depth of more than two miles. They represent an enormous storehouse from which unlimited quantities of various raw materials may be obtained. Since prehistoric times common salt, sodium chloride, has been obtained by the evaporation of sea water. This sodium chloride, so necessary for the maintenance of life, is today one of the basic raw materials of modern industry. Within recent years other chemicals, such as the compounds of magnesium and bromine, have been recovered in vast quantities from the waters of the sea. Products of the ancient seas, accumulated over geologic time, such as limestone and petroleum, are essential materials for present civilizations. Within the seas are myriad forms of plant and animal life. The catching of fish gives employment to many thousands of persons, and these many thousands sell the products of

their labor to many millions for food. To further exploit the seas and use them as a source of fresh water is a matter now receiving some attention.

Acknowledgment

The authors wish to acknowledge financial aid from the Office of Naval Research under provisions of Contract N8onr-520/III between the Office of Naval Research and the University of Washington.

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