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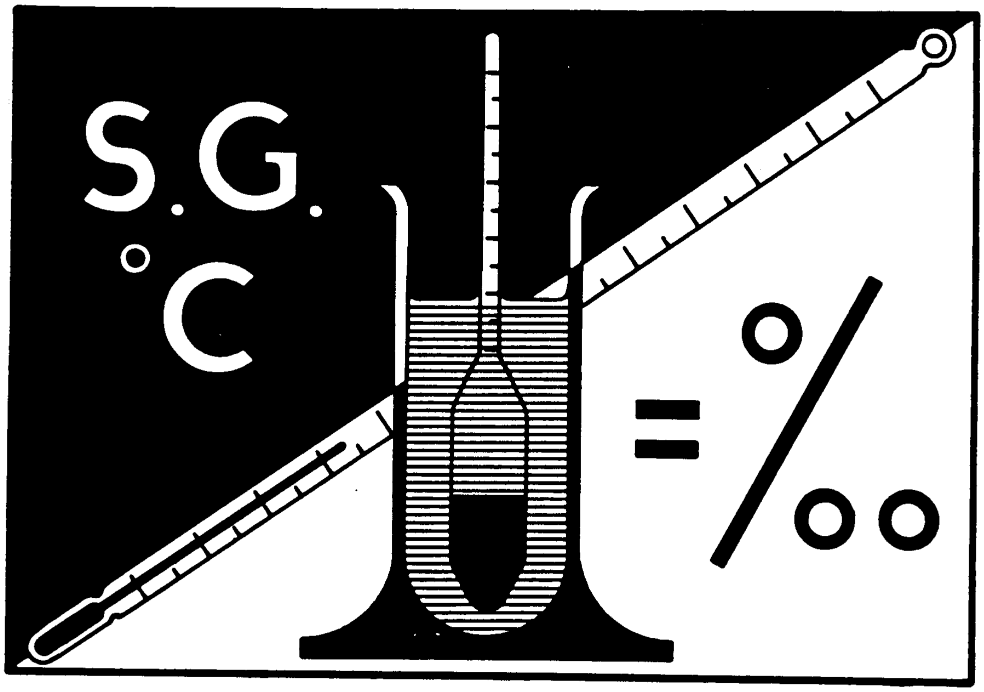
ARTIFICIAL SEA WATER FOR SHELLFISH TANKS



INCLUDING NOTES ON SALINITY AND SALINITY MEASUREMENT

P.C. WOOD AND P.A. AYRES

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ARTIFICIAL SEA WATER FOR SHELLFISH TANKS, INCLUDING NOTES ON SALINITY AND SALINITY MEASUREMENT

by P. C. Wood and P. A. Ayres

FOREWORD

This leaflet is an updated revision of MAFF Laboratory Leaflet (New Series) No. 13, prepared by P. Wood and published in 1966, entitled 'Lobster storage and shellfish purification: notes on the salinity of seawater and the use of artificial seawater in commercial installations'.

INTRODUCTION

Within recent years there has been a steady increase in the number of shore installations where lobsters are stored or oysters are purified. The water used in these tanks is usually pumped from the sea, but in some cases an artificial sea water is made up from a mixture of simple salts. Where water is taken from an estuary there is a risk that the salinity may at times be too low to permit the normal activities of the shellfish. The object of this leaflet is to describe how the salt content of sea water can be measured, and how salts may be used to increase the salinity of natural sea water, or for the manufacture of artificial sea water for use in lobster storage and shellfish purification tanks.

1. WHAT IS SALINITY AND HOW DOES IT VARY?

The salt content or salinity of sea water is usually expressed as the number of parts by weight of salt in one thousand parts by weight of water. The unit 'parts per thousand' is usually indicated by the symbol $^o/oo$. Thus water having a salinity of $35^o/oo$ contains 35 lb of salt in 1 000 lb of water. Since a gallon of water weighs 10 lb, water of salinity $35^o/oo$ contains 35 lb of salt in 100 gallons. For those wishing to use metric units, water of salinity $35^o/oo$ contains 35 g of salt in 1 litre of water, or 35 kg in 1 cubic metre (m^3).

The salinity of sea water usually decreases as one moves from the open sea into an estuary, as a result of the increased quantity of fresh water present. In the open sea around the British Isles salinities of $34^o/oo$ or more are usual, with only small changes during the seasons. However, in tidal estuaries, salinities are generally lower and subject to considerable variation. Salinities are usually lower in winter than in summer, lower at low tide than at high tide, and lower at neap than at spring tides. At the seaward end of a typical east coast oyster-producing estuary the maximum range of salinity during the year may be from $26-34^o/oo$, whilst at the upper limit of oyster cultivation the salinity in winter may vary from $10-25^o/oo$ during a tidal cycle. In addition to these changes, local areas of low salinity may be found close inshore adjacent to freshwater discharges from streams or outfall pipes.

Water near the surface may be of lower salinity than that found at deeper levels, for there is a tendency for fresh water, or sea water containing a large proportion of fresh water, to remain on the surface. For this reason, intakes to sea-water installations should be placed on or near the bottom in as deep water as possible.

2. THE MEASUREMENT OF SALINITY

It is difficult to measure the salt content of sea water by direct means, but a good estimate of the water quality can be obtained by measuring its specific gravity (SG) with a hydrometer. For rough work, only the specific gravity need be considered, but for a more accurate estimate the temperature of the water must also be taken so that salinity can be obtained by reference to a table or a graph. Distilled water has a specific gravity of about 1.000 and 'full' sea water of about 1.026, but these values vary a little according to the water temperature. It is important to distinguish clearly between salinity and specific gravity when describing a sea water.

For the tank operator there are a number of hydrometers available for the measurement of specific gravity, but one which is particularly useful is listed as: Soil testing hydrometer, long stem, to B.S. 1377, range 0.995-1.030 SG at 20°C. If other instruments are used, care should be taken to ensure that the graduations are sufficiently wide apart to permit accurate reading, and that the instrument, if used with the tables and graph appended to this report, is calibrated between 17.5 and 20°C. When ordering a hydrometer it is advisable to ask for a glass hydrometer jar of suitable size to go with it.

To determine the specific gravity, a sample of water should be taken from the tanks or from the incoming sea water in a clean vessel, free from oil or grease. The bulb and stem of the hydrometer should be cleaned and freed from adhering particles, salt crystals pieces of cotton wool, grease, etc., and immersed in water in the hydrometer jar. Only the very top of the stem should be handled, for grease from the hand may affect the readings. Any bubbles of air seen on the side of the hydrometer bulb should be removed by gentle agitation of the instrument, or by wiping with a clean cloth. The hydrometer should then be allowed to settle, and the reading of the hydrometer taken <u>with the eye level with the water surface</u>. This is why it is important to place the hydrometer in a glass jar when the reading is taken; accurate readings cannot be made when the hydrometer is viewed from above. The readings shown on the hydrometer are for specific gravity but only the last two numbers are shown, i.e. 1.020 is usually marked as '20' on the scale.

3. SALINITY REQUIREMENTS FOR SHELLFISH TANKS

Lobsters are typically coastal animals found in waters having a salinity of 33°/oo or more. They cannot tolerate low salinities, or rapid changes of salinity, and do not occur in large numbers in estuaries or other areas subject to low salinities. It is possible to store lobsters in water having a salinity down to 25°/oo, and even less when water temperatures are below 10°C (50°F), but the minimum value usually considered acceptable in commercial storage units is 27°/oo. Lobsters exposed to low salinity may weaken and die, with a characteristic swelling in the middle of the body, between the head and the tail region. This is caused by the uptake of water.

Native, Portuguese and Pacific oysters and hard clams are typically estuarine shellfish which can tolerate relatively low and rapid changes of salinity. Although these shellfish may become gradually adjusted to the very low salinities which often result from the increasing quantities of fresh water entering an estuary in autumn and winter, the minimum salinity normally considered acceptable in purification plants is 25°/oo for native oysters, 20.5°/oo for Portuguese and Pacific oysters and 20°/oo for hard clams. In comparison, the minimum salinity for mussel purification is 19°/oo. Shellfish held in water of too low a salinity will not open, and purification cannot take place; prolonged exposure to low salinity may ultimately lead to death.

For normal purposes a measurement of specific gravity is adequate for ensuring that water has a salinity equal to or greater than the minimum values shown above. The minimum specific gravities of sea water recommended are as follows:

Shellfish	Minimum specific gravity
For storage	
Lobsters	1.023
For purification	
Native oysters	1.022
Portuguese and Pacific oysters	1.018
Hard clams	1.017
Mussels	1.016

Sea water at any temperature having a specific gravity equal to or greater than the values shown is suitable for use in tanks for the purpose indicated.

If water taken into a tank has a specific gravity near to or below that recommended (say 1.021 for native oysters) it is well worth making a more accurate estimate of the salt content by taking the water temperature and converting the values to salinity. This can be done by reference to Figure 1. Starting at the observed temperature, move the finger vertically until it reaches the line for the observed specific gravity. At this point move the finger horizontally to either side of the graph, until it cuts the scale where the salinity is shown. Thus water having an SG of 1.020 at 5°C (41°F) indicates a salinity of 24°/oo, which is suitable for the purification of Portuguese oysters, clams and mussels, but not native oysters, nor for the storage of lobsters. The minimum salinities normally accepted in tanks holding the various shellfish are shown on the graph by the thick horizontal lines.

If the observed salinity is below the minimum, then a salt mixture as described later should be added. For those not wishing to use the graph Table 1 has been prepared, showing the minimum specific gravity of sea water at several temperature ranges in various types of installation. It can be seen from the table that as the water temperature rises, the minimum acceptable specific gravity falls below that given in the rough guide above. Thus when the specific gravity is less than that recommended in the rough guide, and particularly where large volumes of water are involved, the accurate measurement of salinity using a temperature correction may indicate that water of adequate salinity is present, and so save the additional cost and time involved in adding salts.

Table 1 Minimum specific gravity of water for use in shellfish installations

Water temperature		Storage of lobsters	Purification of			
°F	°C		native oysters	Pacific and Portuguese oysters	hard clams	mussels
Up to 50	Up to 10	1.023	1.022	1.018	1.017	1.016
51-59	10.1-15	1.022	1.021	1.017	1.017	1.016
60-68	15.1-20	1.021	1.020	1.016	1.016	1.015
69 and above	20.1 and above	1.020	1.019	1.015	1.015	1.014

In this leaflet detailed attention is given only to those British species stored or purified commercially, although within recent years there has been increased interest in the live storage of other shellfish.* The American lobster (Homarus americanus) is known to tolerate salinities suitable for the storage of British lobsters. The crawfish (Palinurus vulgaris, otherwise known as the spiny lobster or langouste, is stored in tanks in the south-west of England, where salinities are relatively high, and being an offshore animal is probably intolerant of very low salinities. Experiments at the Burnham laboratory indicated that a salinity of 28°/oo was too low, whilst 32°/oo (approximately SG 1.025-1.026) was satisfactory. The Norway lobster (Nephrops norvegicus), known as Dublin Bay prawn, langoustine, or scampi, is an offshore animal, and in the absence of more detailed information it is recommended that water for its storage should have a salinity of at least 34°/oo (approximately SG 1.027-1.028). When artificial sea water is used the weight of salts should be increased, above that shown for lobsters in Table 3, by approximately 7% for crawfish and 13% for Norway lobsters. The edible crab (Cancer pagurus) should be held in water containing at least 30°/oo of salt (SG 1.024-1.025).

Of the remaining commercial species of shellfish, winkles (Littorina littorea) are often stored in sea water prior to dispatch to market. These shellfish are estuarine animals able to tolerate a wide range of salinities, at least down to 20°/oo (approximately SG 1.016-1.017), and probably lower. Escallops (Pecten maximus), although not normally stored commercially, can be held in tanks of sea water of good salinity. In the absence of any more precise information, it is recommended that escallops should not be held in water of salinity less than about 35°/oo (approximately SG 1.027-1.028).

4. THE USE OF SALTS FOR MAKING ARTIFICIAL SEA WATER

Sea water consists of a complex mixture of salts, many of which are present in very small quantities, but for lobster storage and shellfish purification water containing a mixture of five simple salts is adequate. The mixture recommended in this leaflet was devised originally for the storage of lobsters, and has been successfully used in Britain in many commercial storage units, but it is also suitable for use in shellfish purification plants. The salt mixture may be used for making up an artificial sea water from tap water, or for increasing the salinity of natural sea water. When more than one type of shellfish is present in an installation, the water should be made suitable for the shellfish requiring the highest salinity.

The quantities of each of the five salts required for making up amounts of between 50 and 1 000 lb of the salt mixture are shown in Table 2. It is important to note the following: (a) always specify both the name and the chemical composition when ordering, for there are several compounds having the same name but different chemical composition; (b) common salt should be of 'pure vacuum dried' or cooking quality; rock salt is not satisfactory; (c) if flake calcium chloride is not available, hydrated calcium chloride ($Ca\ Cl_2.6H_2O$) may be used, but the weight should be increased by 50%, i.e. for 50 lb of salt mixture 2 lb 10 oz are required; do not use anhydrous calcium chloride.

In Table 3 are shown the individual weights of each salt and the weights of the salt mixture required for making up between 50 and 1 000 gallons† of artificial sea water suitable for lobsters, oysters and hard clams respectively. It has not been found economic

* The Latin names of the species of shellfish at present stored or purified commercially in this country are as follows: lobster (Homarus gammarus); native oyster (Ostrea edulis); Portuguese oyster (Crassostrea angulata); Pacific oyster (Crassostrea gigas); mussel (Mytilus edulis); hard clam (Venus mercenaria).

† In this leaflet gallons = imperial gallons.

Table 2 Composition of artificial salt mixture

Common names of salts	Chemical composition	Weight of each salt needed to make up the following weights of salt mixture										
		50 lb		100 lb		250 lb		500 lb		1000 lb		100 kg
		lb	oz	lb	oz	lb	oz	lb	oz	lb	oz	kg
Sodium chloride (common salt)	NaCl	32	14	65	12	164	6	328	12	657	8	65.75
Magnesium sulphate (Epsom salt)	$MgSO_4.7H_2O$	8	2	16	4	40	10	81	4	162	8	16.25
Magnesium chloride	$MgCl_2.6H_2O$	6	8	13	0	32	8	65	0	130	0	13.00
Flake calcium chloride	$Ca\ Cl_2.2H_2O$	1	12	3	8	8	12	17	8	35	0	3.50
Potassium chloride	KCl		14	1	12	4	6	8	12	17	8	1.76

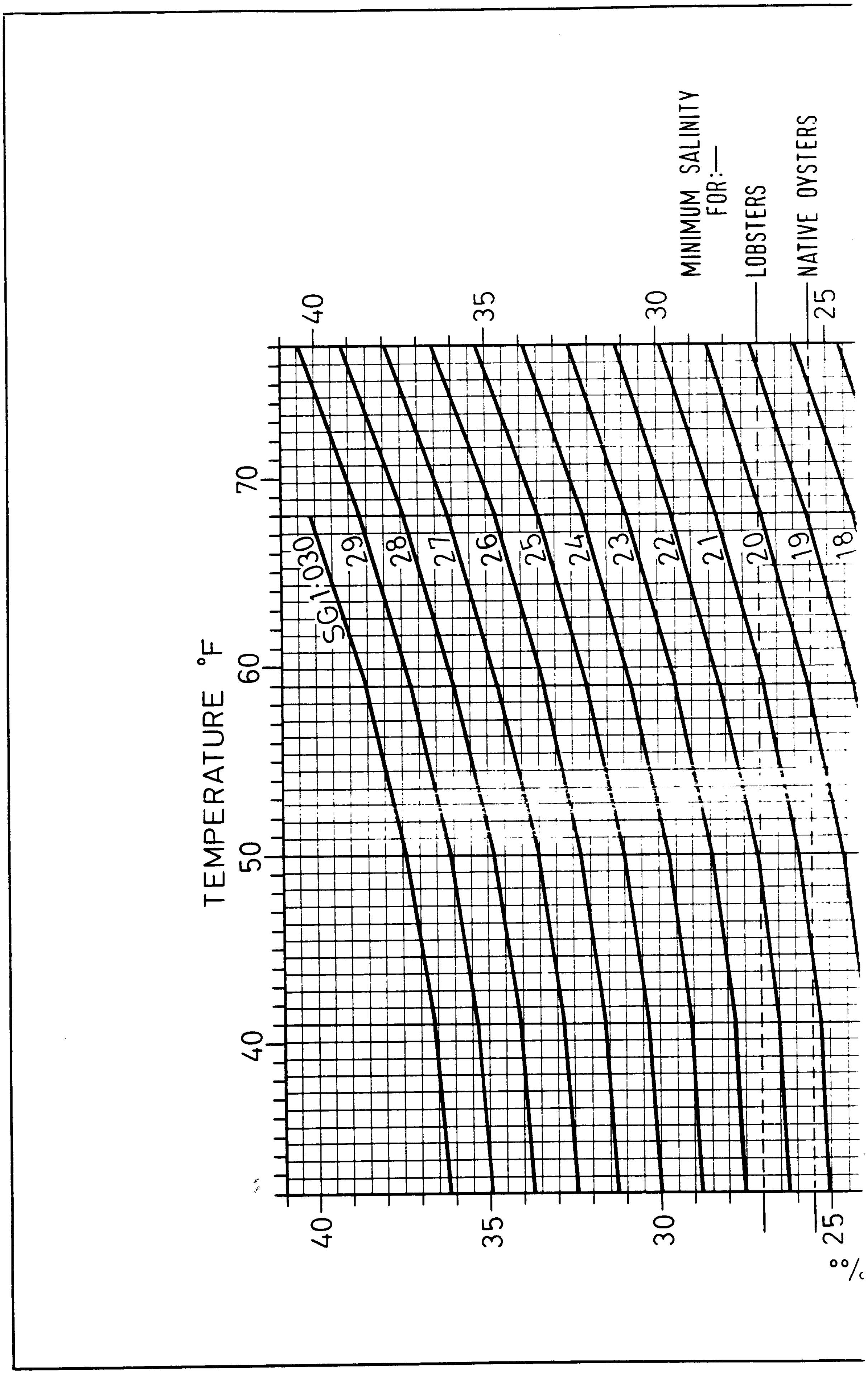
to make up artificial sea water for the purification of mussels, although there is no practical reason why this should not be done.

The cost of making up artificial sea water may vary widely, depending on the supplier, the area of purchase and the quantity of each salt purchased. Commercial or agricultural grades, obtained through industrial chemists, are suitable and are usually much cheaper than salts to BP (British Pharmacopeia) or analytical reagent standards: the latter are of an unnecessarily high quality. It is therefore well worth making a number of enquiries before buying. One hundredweight (50 kg) lots are always considerably cheaper than smaller quantities. The minor salts are obtainable in quantities of less than one hundredweight, but at considerably higher prices. If salts are bought in quantity and stored before use, airtight containers of plastic or metal should be used (e.g. plastic dustbins) to prevent absorption of water; the salts may be mixed together and stored until required. Salt mixtures, suitable for direct addition to fresh water, are available from several commercial suppliers, but the cost of these mixtures is high compared with those made by the user from component salts as detailed here.

5. HOW TO MAKE UP ARTIFICIAL SEA WATER

The volume of the tank should be checked by making measurements of the length, breadth and average depth of the water, taking into account any irregularities of the internal shape and also water in channels, pipes, etc. The volume in gallons may be obtained by multiplying the total volume in cubic feet by $6\frac{1}{4}$. Where small prefabricated tanks are used it is important to check their volume because the nominal capacity, i.e. that given by the manufacturer, is often very different from the actual working capacity. It is also inadvisable to estimate the volume of an installation from the time taken to fill it with a pump, the flow of which is not accurately known; the actual pumping rate seldom coincides with that given by the manufacturer, on account of the method of installation and a general reduction in the efficiency of pumps with age. Having determined the water volume, the weight of salts required in the tank is obtained from the weights given in the appropriate part of Table 3.

The salts may be weighed out in a quantity suitable for one filling, or for several fillings, but in the latter case care must be taken to ensure that the minor salts are evenly distributed throughout the mixture. This difficulty can be overcome by keeping down the bulk and mixing together all the salts except the common salt, which is then added to the



TEMPERATURE °F
40
50
60
70
MINIMUM SALINITY FOR:—
LOBSTERS
NATIVE OYSTERS
SG 1:030
29
28
27
26
25
24
23
22
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20
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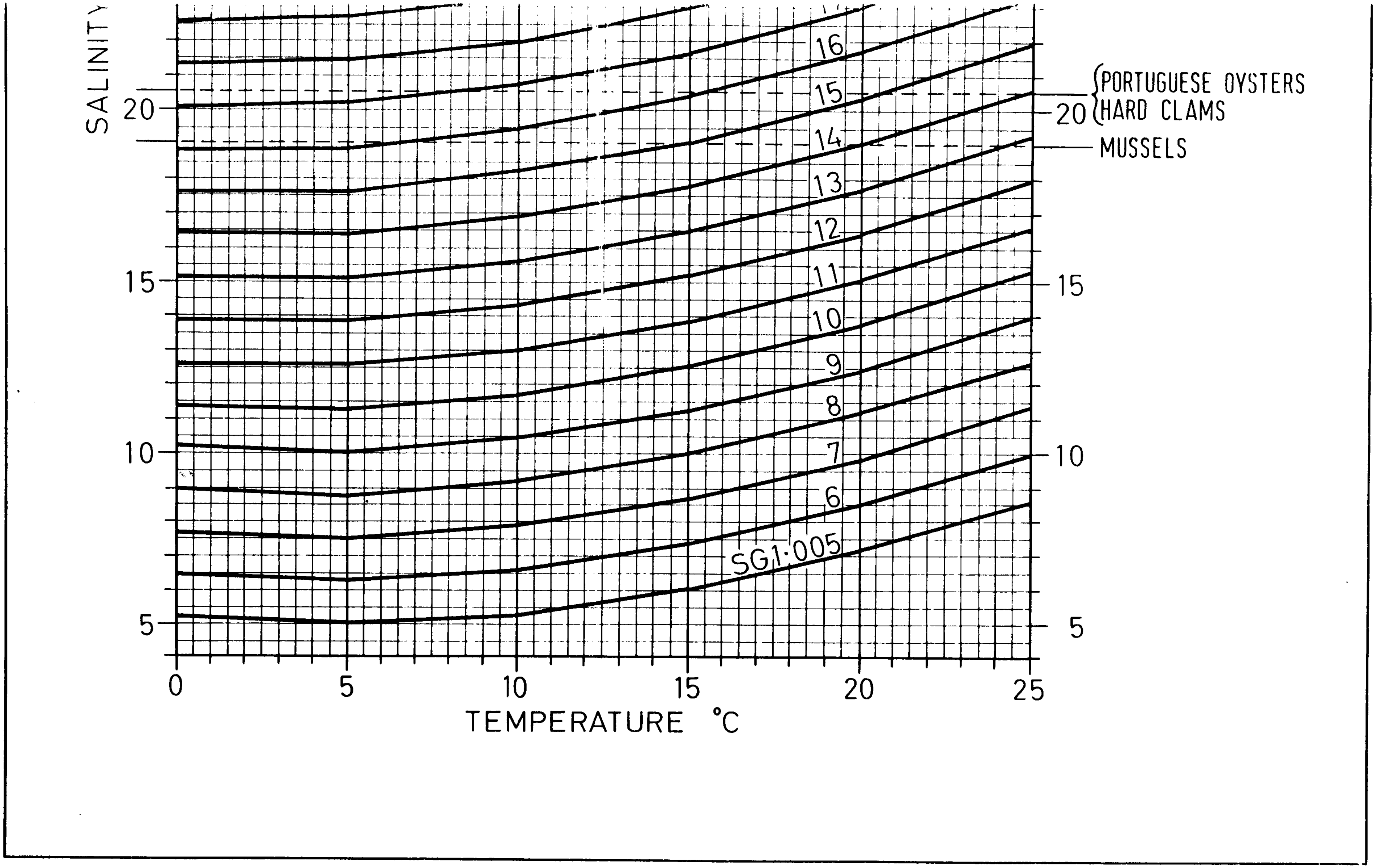

Figure 1 Graph for conversion. Specific gravity ~ salinity.

tank in the appropriate amount at the same time as the mixture. Salt mixture not used immediately should be stored in clean, dry containers. Before, during or after filling the tanks with water, the salts should be distributed throughout the tanks in a thin layer, beneath the inlet or near the outlet(s) of the circulating system, in order to speed up solution. Most of the salts will pass into solution rapidly but a small quantity may remain to form a fine white precipitate which may take several hours to disappear. When the bulk of the salts has dissolved, the salinity should be checked with a hydrometer, and if satisfactory the shellfish may be immersed.

Table 3 Composition of artificial sea water for use in lobster storage and shellfish purification units (for further details see Table 2)

Common names of salts	Weight of salts required by the following volumes of water						
	50 gal		250 gal		1000 gal		1 litre
	lb	oz	lb	oz	lb	oz	g
(a) For lobster storage							
Sodium chloride	11	11½	58	9	234	6	23.51
Magnesium sulphate	2	14	14	6	57	8	5.74
Magnesium chloride	2	4½	11	6	45	8	4.55
Flake calcium chloride		9½	2	15	11	12	1.19
Potassium chloride		4½	1	6	5	8	0.56
Total	17	12	88	10	355	0	35.55
These mixtures will give artificial sea water having a salinity of approximately 30°/oo							
(b) For purification of native oysters							
Sodium chloride	10	9	52	13	211	4	21.08
Magnesium sulphate	2	9½	12	15	51	12	5.18
Magnesium chloride	2	1	10	5	41	4	4.12
Flake calcium chloride		8½	2	10	10	8	1.06
Potassium chloride		4	1	4	5	0	0.50
Total	16	0	79	15	319	12	31.94
These mixtures will give artificial sea water having a salinity of approximately 27°/oo							
(c) For purification of Portuguese and Pacific oysters and hard clams							
Sodium chloride	8	9½	42	15	172	12	17.15
Magnesium sulphate	2	1½	10	7	41	12	4.18
Magnesium chloride	1	11	8	7	33	12	3.37
Flake calcium chloride		7	2	3	8	12	0.87
Potassium chloride		3½	1	1	4	4	0.44
Total	13	0½	65	1	261	4	26.01
These mixtures will give artificial sea water having a salinity of approximately 22°/oo							

Water used for making artificial sea water should be of drinking quality. If an excessive quantity of chlorine is present, this will escape to the atmosphere during circulation. Extremely acid water, such as that from a peat catchment area or from certain mountainous areas, may be unsuitable for oyster purification, and, in the cases of doubt, advice should be sought from the chemist of the local water undertaking. Artificial sea water for oyster purification should have a pH not less than 6.5.

6. THE USE OF SALTS FOR INCREASING THE SALINITY OF NATURAL SEA WATER

In estuaries and inlets which receive substantial quantities of fresh water, the salinity may at times fall below the minimum required for shellfish. Where a new installation is planned the tank should be sited so that water of high salinity can be obtained at all times of the year, and for this purpose the proposed site should be examined during a wet spell, because water at a point which is of 'full' salinity in summer may fall to 20°/oo or lower during a prolonged wet spell. Whenever possible salinity measurements should be made on samples taken at neap and spring tides from the same position and depth as the proposed intake; visual examination of the site without reference to salinity measurements may later lead to disappointment, for there is a tendency to underestimate the effect of fresh water in the lower parts of an estuary.

At established installations water of the highest salinity can usually be obtained during the last hour of the flood tide, and it is usually of a considerably higher salinity during the period of spring tides than at neaps. In places where the catchment area is a long way from the estuary the effect of heavy rain may not show in an estuary until several days later; after a period of heavy rain there is usually further delay before the salinity returns to normal. Where there are persistently low salinities consideration should be given to extending the water intake to low-water mark, or even to a deep-water channel if this is not too far away.

When existing pipe lines are extended the rate of pumping may be substantially reduced by the friction of the longer pipe unless the pipe is of adequate diameter. The intake should be located on or near the sea-bed so as to take advantage of water of the highest salinity, and be as far from sewage and industrial outfalls as possible. Outfalls containing gas-works liquors can be particularly troublesome because extremely small quantities of these effluents in water taken into shellfish tanks can lead to the development of tastes similar to those of some disinfectants.

When water of low salinity is taken into an installation the natural salt content may be increased by the addition of the salt mixture shown in Table 2. As a quick guide to the weight of salt mixture needed for raising the salinity, the following table shows the weights of salts that must be added for every unit of salinity (1°/oo) or SG (0.001) that the water is below the recommended value.

	Weight of salt mixture to be added to: 100 gal		1000 gal		1 cubic metre
	lb	oz	lb	oz	kg
To increase salt content by 1 unit of:					
Salinity (°/oo)	1	3	11	14	1.18
Specific gravity (0.001)	1	7	14	6	1.43

Thus, to increase the salinity of water from 15 to 20‰, (20-15 = 5) x 1 lb 3 oz = 5 lb 15 oz (or about 6 lb) of salt mixture must be added to every 100 gallons of water. If only the specific gravity is known, then to increase water from 1.016 to 1.020, each 100 gallons will require (1.020-1.016 = 4 units of SG) x 1 lb 7 oz = $5\frac{3}{4}$ lb of salt mixture.

When water in lobster storage units is just below the required salinity it is possible to increase the salinity by the addition of common salt (sodium chloride) only. It is essential that the salt balance is not altered too much, and it is recommended that the use of common salt by itself be restricted to waters having an SG of 1.019 or more; for waters of lower salinity, the full salt mixture should be added. The salinity of water for use in oyster purification plants should be increased by the addition of the full salt mixture shown in Table 2, for it is essential that the oysters not only remain alive, but continue to function actively, so that purification can take place.

7. THE PLANNING OF NEW INSTALLATIONS OR THE EXTENSION OF EXISTING ONES

In installations which hold shellfish the availability of water of adequate salinity at all times is of prime importance. Care taken in the selection of a site can save considerable cost later, particularly where tanks holding large volumes of water are involved. For this purpose salinity surveys can be speeded up by the use of more advanced equipment than that described here.

For problems concerned with salinity or with the design and construction of installations in which shellfish are stored or purified, the staff of the Ministry's Fisheries Laboratories at Conwy (North Wales) and Burnham-on-Crouch (Essex) are available for consultation.

For those who need advice on how to store lobsters or purify oysters or mussels the following publications may be of assistance:

AYRES, P. A. and WOOD, P. C., 1977. The live storage of lobsters. Laboratory Leaflet, MAFF Directorate of Fisheries Research, Lowestoft, No. 37, 9 pp.

McLEESE, D. W. and WILDER, D. G., 1964. Lobster storage and equipment. Fisheries Research Board of Canada, Bulletin No. 147, 70 pp. (This paper deals with lobster storage in Canada.)

REYNOLDS, N., 1956. A simplified system of mussel purification. Fishery Investigations, Series 2, Vol. 20, No. 8, 18 pp.

THOMAS, H. J., 1969. Lobster storage. HMSO, Edinburgh, 37 pp. Reprinted, with amendments, 1974.

THOMAS, H. J., 1969. Handling lobsters and crabs. (3rd revised edition). DAFS Marine Lab., Aberdeen, 14 pp.

THOMAS, H. J., 1962. Refrigerated storage of lobsters. Scottish Fisheries Bulletin No. 17, pp. 16-20.

WOOD, P. C., 1961. The principles of water sterilization by ultra-violet light and their application in the purification of oysters. Fishery Investigations, Series 2, Vol. 23, No. 6, 49 pp.

WOOD, P. C., 1969. The production of clean shellfish. MAFF Laboratory Leaflet, No. 20, 16 pp.

SUMMARY OF THE IMPORTANT POINTS

1. Minimum salt content of sea water (for details see Figure 1 and Table 1)

Shellfish	Minimum salinity (°/oo)	Minimum SG (rough guide)
Lobsters	27.0	1.023
Native oysters	25.5	1.022
Pacific and Portuguese oysters	20.5	1.018
Hard clams	20.0	1.017
Mussels	19.0	1.016

2. Artificial sea water

To make up artificial sea water (composition as in Table 2)

Shellfish	Weight of salt mixture for: 100 gal		1000 gal		Details
	lb	oz	lb	oz	
Lobsters	35	8	355	0	Table 3(a)
Native oysters	32	0	320	0	Table 3(b)
Portuguese oysters, Hard clams	26	1	260	10	Table 3(c)

To increase salinity of natural sea water

	Weight of salt mixture for 100 gal		Details
	lb	oz	
For each unit of salinity (°/oo) that is required	1	3	Page 9
For each unit of SG (0.001) that is required	1	7	Page 9

3. Use of common salt instead of complete salt mixture

Add to water in lobster storage tanks when SG is 1.019 or more. Do not use in shellfish purification tanks.

RECENT LABORATORY LEAFLETS

A full list of Directorate of Fisheries Research Publications currently available appears in the Ministry's Catalogue of Departmental Publications, obtainable from: Ministry of Agriculture, Fisheries and Food (Publications), Tolcarne Drive, Pinner, Middlesex HA5 2DT.

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