REVERSE OSMOSIS

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In the article 'Distilling Plants in the Royal Navy' (Vol. 19, No. 1), brief mention was made of the investigation being made into the use of reverse osmosis plants. The intention of this article is to explain the process of reverse osmosis and how useful it might be for producing fresh water in ships.

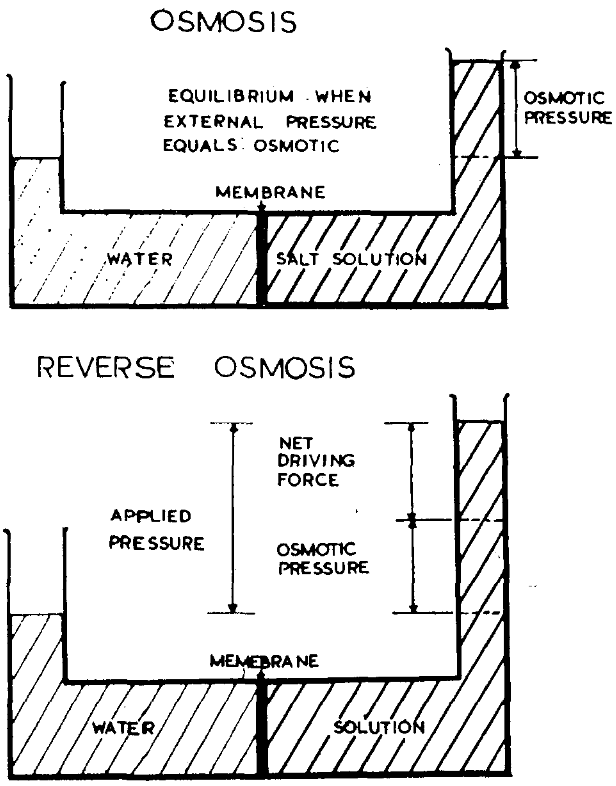

FIG. 1—OSMOSIS AND REVERSE OSMOSIS

Osmosis

Osmosis is a natural phenomenon whereby the water from a weak solution will flow into a strong solution divided from it by a semi-permeable membrane. This process continues until the two solutions are of equal strength, and the rate of flow is at any one time a function of the difference of their strengths. The tendency of the weaker one to flow in to the stronger one may be balanced by putting a pressure on the strong solution which, if further increased, will cause water to flow in the opposite direction, and so we have reached a situation where the strength of the strong solution is being further increased and the solvent being separated from it. This looks very much like a filtration process and is

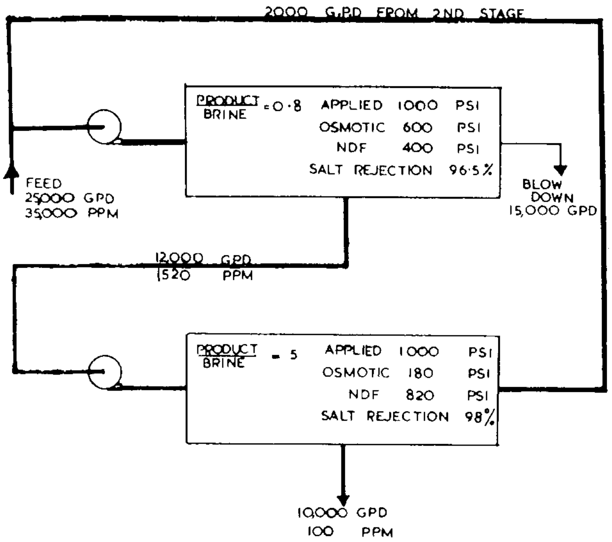

FIG. 2—SIMPLIFIED FLOW DIAGRAM OF 10 000 GALL/DAY REVERSE OSMOSIS PLANT

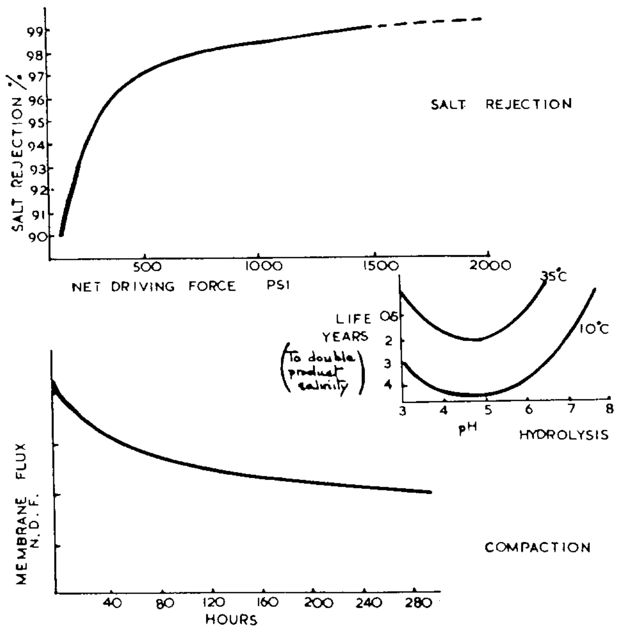

FIG. 3—MEMBRANE CHARACTERISTICS

commonly called Reverse Osmosis. Unlike a filter, however, it is apparent (FIG. 1) that a certain pressure has to be applied before any flow in the desired direction takes place at all and this pressure is a function of the difference of the solution strengths or, more precisely, the difference in their osmotic pressures.

For a practical size water-producing plant, a simplified flow diagram of which is shown in FIG. 2, the mean osmotic pressure which has to be overcome is as high as 600 psi, with a high water recovery product/feed of 45 per cent in the first stage.

Membranes

Membranes occur widely in nature but so far are not easy to manufacture reliably and consistently. There are the conflicting problems of making and supporting a membrane to withstand high pressures thin enough to allow a useful flux rate, without losing sight of membrane life and ease of replacement. With currently available membranes based on cellulose acetate, supported by perforated stainless steel tubes, there is a possibility that a plant can be built of similar size to conventional evaporators with a life between membrane replacements of perhaps 8000 hours.

The characteristics of cellulose acetate membrane show an unexpected bonus in that both salt rejection and flux rate increase with pressure. The incentive to work at very high pressures is somewhat assuaged by a decrease in flux over a period of time due to compaction of the membrane which is more pronounced in high than in low pressures. The power consumption, too, which high pressures demand, needs to be kept within bounds. For example, an increase to an operating pressure from 1000 to 1500 psi in the first stage would increase the net driving force from 400 to 900 and thus increase flux by 125 per cent, which in turn allows a reduction of 55 per cent in the first stage membrane area, saving perhaps one-sixth of the total plant volume but involving an increase of power of 30 per cent, i.e., 47kW to 61kW, and incurring a shorter membrane life.

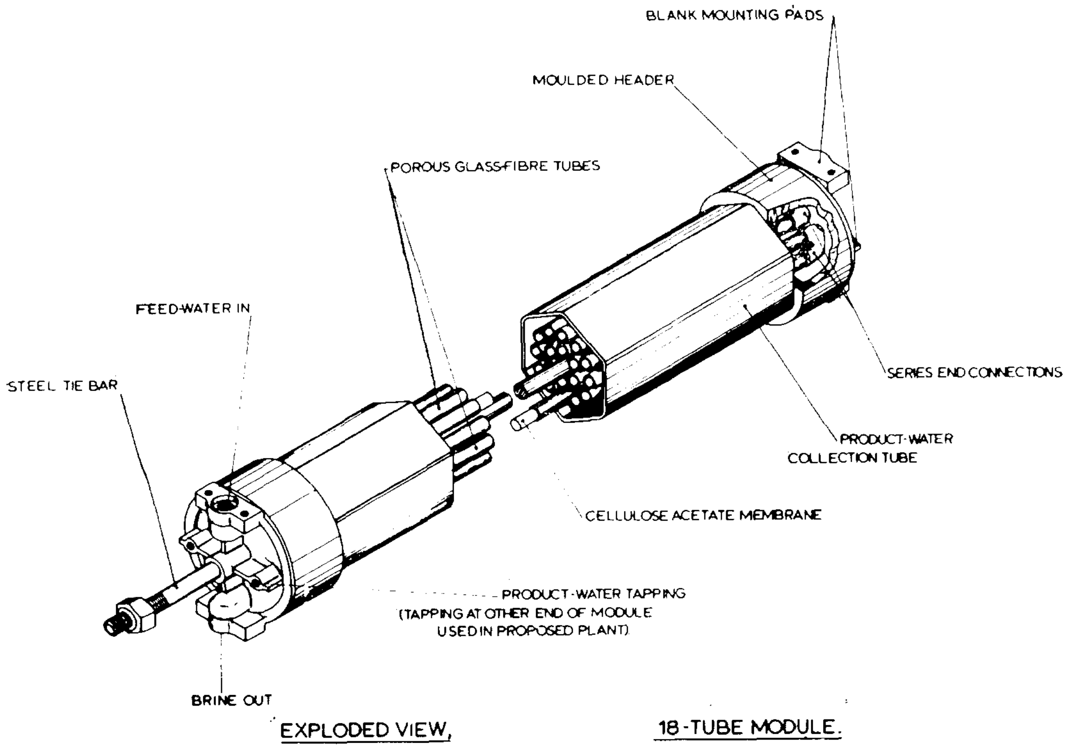

FIG. 4—SECTIONED MODULE

Cellulose acetate membranes are sensitive to the pH of the feed water and their decay will be delayed by acid injection. The curve shown in FIG. 3 is based on laboratory results and it may well be that for any particular membrane the optimum acid treatment is much less than that suggested by this graph.

The Product

The amount of dissolved solids in the product will vary with the state of the membranes, the feed pressure, the density of the sea water, its temperature and the recovery rate in each stage of the plant. It is anticipated that a 2-stage plant will give a product containing between 100 and 400 ppm dissolved solids, which is quite satisfactory for washing, drinking and cooking but would require further processing if it were to be used in boilers, for washing gas turbines or for batteries.

The rate of production will fall slightly during the life of a set of membranes due to compaction and so some spare capacity will be required in the design. More capacity too will be needed if a prudent allowance for random defects is made. These can readily be accommodated because the membranes are contained in separate modules and so a membrane defect may be isolated by turning the whole module to bilge and continuing uninterrupted production with the remaining modules until a convenient opportunity for replacement occurs. FIG. 4 shows a sectioned module, in this case with porous glass fibre support tubes rather than perforated stainless steel described earlier.

Future Prospect

This process is one of continuing improvement in salt rejection, flux and in the robustness of commercially available membranes.

When salt rejections of 99·3 per cent or greater can be consistently obtained, a single-stage plant will be possible which, for potable water production, would

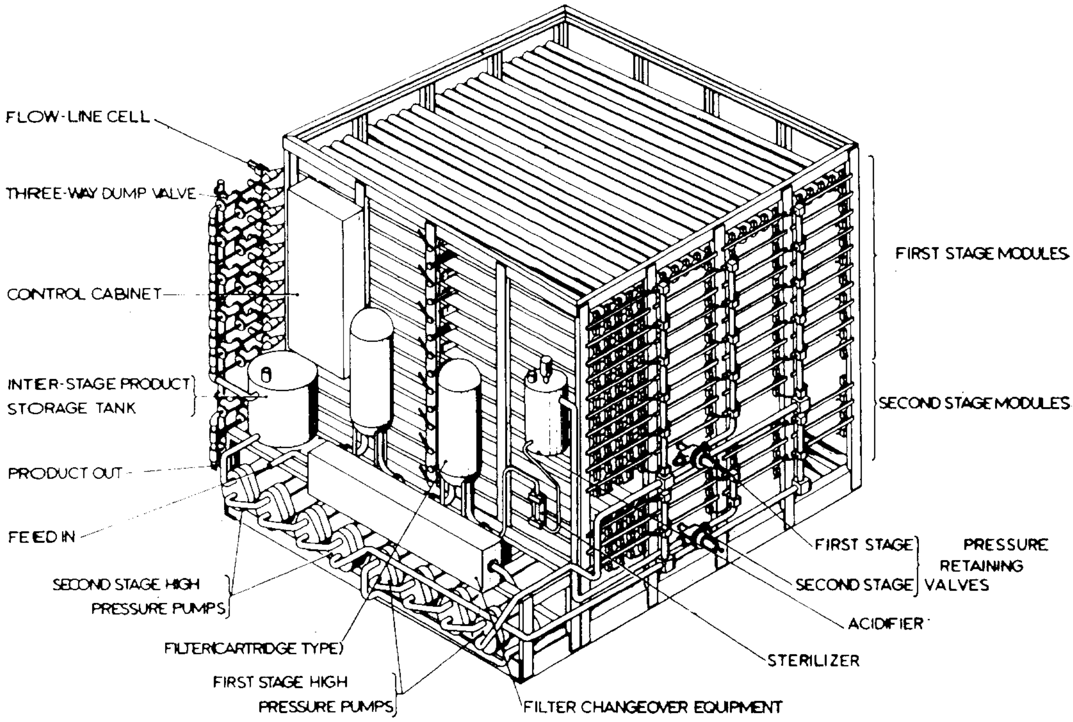

FIG. 5—ISOMETRIC VIEW OF PROTOTYPE PLANT

be very attractive compared with present-day evaporators, requiring little more than their electric power, no steam, only a fraction of their sea-water flow and needing only one pump.

The intermediate step, now in hand, is to obtain and test components to the point of being confident of being able to build a sound 2-stage plant.

Delay in getting to this point is almost wholely concerned with membrane development and essentially the use of reverse osmosis in the Navy depends on this and the employment of gas or Diesel propulsion. FIG. 5 shows a drawing of a projected 2-stage plant the dimensions of which are roughly 8 ft x 9 ft x 10 ft.

For steam ships, conventional evaporators provide the easiest way of producing potable water as they are necessary for making feed water in comparable quantities to the crew's demand. However, a feed consumption of, say, two or three tons a day and a crew demand of 20 might alter the picture in favour of a small evaporator for the steam plant and a reverse osmosis plant for the crew, when single-stage plants become available.

Other Uses of Reverse Osmosis

Reverse osmosis can be used for desalting brackish water in the same way that sea water is desalted. The problem is much easier as the osmotic pressures are much lower and the membranes can be designed for much lower salt rejections and higher fluxes. This allows the use of other membrane materials which are tougher and easier to handle. Perhaps more intriguing is the use of this technique for concentrating solutions rather than for solvent separation. Here the water is removed from the feed as in a desalting plant, but the water is thrown away and the residue retained. Fruit juices and other food concentrates can be produced in this way. The possibility springs to mind of similarly concentrating alcohol solutions with nothing more complicated than a module, a source of pressure and a few litres of wine or beer. There might of course be some snags with the Inland Revenue which would blight the booming potential of this idea to the 'do it yourself' industry!

18th CENTURY DISTILLING PLANT

The following is an extract from Southey's *Life of Nelson*—printed for John Murray, bookseller to the Admiralty and Board of Longitude, in 1814:—

> '1773
>
> The ships were provided with a simple and excellent apparatus for distilling fresh water from salt water, the invention of Dr. Irving, who accompanied the expedition (towards the North Pole). It consisted merely in fitting a tube to the ship's kettle, and applying a wet mop to the surface as the vapour was passing. By these means, from thirty-four to forty gallons were produced every day.'
