

MANUFACTURE OF MEMBRANES FOR DESALINATION AND FILTRATION

FIELD OF THE INVENTION

THIS INVENTION relates to the manufacture of membranes for desalination and filtration.

5 **BACKGROUND TO THE INVENTION**

In many parts of the world, desalinated sea water and desalinated brack water are the only sources of potable water.

Another source of water which, at the moment, is largely untapped is contaminated water flowing from factories and flowing to sewage treatment works.

10 These two sources are usually, at most, treated to bring the water to what is called "river quality" and this water is then allowed to flow into a river and is hence not available for re-use.

15 There are various methods of desalination in use and a common one uses semi-permeable material which allows water to pass through but retains any remaining solids and the dissolved solids. Desalination is usually preceded by a filtration step to remove the bulk of the solids.

Such desalinators use what are called "membranes". Each membrane comprises a perforated core tube and a plurality of rectangular leaves which are fixed to, and then wound around, the core tube. Each leaf is closed along three

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edges and open along the fourth. It is along the fourth edge that the leaf is secured to the core tube. A spacer is provided within each leaf to prevent it collapsing.

5 Spacers are also provided between leaves. Water to be treated flows in the dissolved solids retention passages between the leaves, permeates through the material of the leaves into the permeate passages within the leaves and flows from the permeate passages to the inside of the tube. Brine flows along the membrane from one end to the other, remaining in the retention passages, and exits through a brine outlet.

10 The objects of the present invention are to provide an improved membrane both for desalination and for filtration and an improved method of manufacturing such a membrane.

BRIEF DESCRIPTION OF THE INVENTION

15 According to one aspect of the present invention there is provided a spiral wound membrane which comprises an elongate web of a material which allows water to pass through but inhibits the passage of solids and/or dissolved solids and which has been folded to zig-zag form to produce a stack of layers joined to one another by reverse bends, a perforated tube, the ends of the web forming the stack being secured to the tube, said stack being wound around the tube, there being spacers between the layers, the spacers holding the layers apart to form water
20 flow passages, alternate water flow passages having the ends thereof transverse to said bends sealed closed, said alternate passages being closed by reverse bends at the radially outer ends thereof and being in communication with the perforations of

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the tube at the radially inner ends thereof.

The spiral wound membrane can further include strengthening tapes which extend across the web coincident with said bends, each tape extending on both sides of the respective bend.

5 According to another aspect of the present invention there is provided a method of manufacturing a method of manufacturing a spiral wound membrane which comprises zig-zag folding an elongate web thereby to produce of a stack of layers with reverse bends in the web between layers, the web being of a material which allows water to pass through but inhibits the passage of solids and/or
10 dissolved solids, inserting a spacer into the gap between each top layer of the formed stack and the layer which is being placed on it, said spacers being inserted alternately from opposite sides of the stack, attaching the free ends of the top and bottom layers of the stack to a perforated tube, and winding the stack about the tube.

15 The method can include the further step of applying adhesive along the edges of the web so that alternate gaps are closed along those edges of the stack which are transverse to the bends.

To strength the web, tapes can be adhered to it, the tapes extending in the direction of the width of the web and being spaced apart at intervals which are
20 such that, when reverse bends are created in the web during folding and stacking, it

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is the parts of the web to which the tapes are adhered that have said bends formed in them.

The method can further comprise reciprocating a head back and forth in the direction of the length of the web and feeding out the web from the head to lay down successive layers. To facilitate laying down of the layers, the method can include the step of advancing bars from opposite edges of the web to overlay that layer which is for the time being the top most layer, displacing the head in the reverse direction to pull the web against the bars which have been advanced. Said bars are preferably in the form of rotatable rollers.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a pictorial view of a reverse osmosis water desalination unit including a cylindrical casing;

Figure 2 is a longitudinal, diametrical section through the unit of Figure 1 and showing some of the components separated for ease of illustration;

Figure 3 is an "exploded" pictorial view, to a larger scale and also in section, of the unit of Figure 1;

Figure 4 is a pictorial "exploded" view of the components which form an end closure;

Figure 5 is a section illustrating an assembled end closure;

Figure 6 illustrates the construction of the membrane of the reverse osmosis desalination unit of Figure 1;

Figure 7 diagrammatically illustrates a method of manufacturing a spiral

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wound membrane; and

Figure 8 further illustrates the manufacture of a spiral wound membrane.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring firstly to Figure 1, the reverse osmosis desalination unit 10
5 illustrated comprises a cylindrical casing 12 and end closures 14 only one of which
can be seen in Figure 1. Within the casing 12 (see Figures 2 and 3) there are three
end-to-end spirally wound reverse osmosis membranes 16.1, 16.2 and 16.3. The
construction of the membranes will be described in more detail hereinafter. For the
purposes of the description of Figures 2 and 3 it is noted that each membrane 16.1,
10 16.2 and 16.3 comprises a core tube 18 with leaves 20 of semi-permeable material
wound around them.

Upstream of each membrane 16 there is a flow distributor plate 22.
The plates 22 are described more fully in specification WO 97/21630. Two short
tubes 24 connect the three core tubes 18 end-to-end so that water that has
15 permeated through the semi-permeable material of the leaves 20 can flow to the
outlet end of the core tube of the membrane 16.1. A plug 26 closes that end of the
core tube 18 of the membrane 16.3 which is remote from the tube 24 that connects
the core tube of the membrane 16.3 to the core tube of the membrane 16.2.

The casing 12 is produced on an elongate mandrel (not shown) which
20 tapers from one end to the other, the taper being for the purpose of facilitating
release of the casing 12 from the mandrel. To further facilitate release of the casing,

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the mandrel can be of steel which has been chromed to produce a smooth surface.

To manufacture a casing 12, the two components of a settable resin are mixed. The resin mixture must be such that it can be sprayed, painted or otherwise applied to the surface of the mandrel to form a layer. The resin, once set, must have some resilience so that it can stretch in the direction of the length of the casing and must also have memory so that, after stretching, it returns to its original length.

Rovings of glass fibre are unwound from one or more reels, passed through a resin bath, and then through scrapers to remove excess resin. The bath and scrapers constitute a winding head (not shown). The free ends of the rovings are pressed against the tacky resin layer on the mandrel so that they stick. The mandrel is then rotated to pull the rovings from the reels and simultaneously the winding head reciprocates back and forth along the mandrel so that the rovings are applied the full length of the mandrel.

Once part of the thickness of the casing has been wound, using the resin coated rovings, electrical coils (not shown) are wound onto the part formed casing. Winding using the resin covered rovings then continues. The electrical coils are thus embedded in the walling of the casing. The function of these are is described in specification WO 98/30501.

Once the casing has the requisite wall thickness, it is covered

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externally using a gel coat, to obtain the requisite surface finish.

Suitable materials for the casing are:-

The internal layer (liner) URCO/6414 A+B

Rovings DR 2400tex

5 Resin SP4578 Hardener SP4578-1

Two rings 28, each with a number of circumferentially extending external flanges 30 (see Figures 4 and 5), are slid one onto each end of the mandrel before winding starts. The resilient layer extends from one ring to the other. The rings 28 are embedded in the ends of the casing 12 as winding proceeds. Because of the flanges 30, the rings 28 are interlocked with the glass fibre reinforced material of the casing and are immovable with respect to it. In Figures 3 and 4 the rings 28 are shown separated from the casing 12. The "imprint" of each ring 28 is shown withing the casing 12.

Each ring 28 also has an internal circumferentially extending groove 32. (See particularly Figure 4).

A multi-part ring 34 (also best shown in Figure 4) is fitted into each ring 28. Each ring 34 comprises three or four arcuate parts and the rings 34 are assembled within the rings 28. Each part of each ring 34 has an external rib extending from end-to-end. The part ribs co-operate when the ring 34 is assembled to form a circumferentially extending rib 36 which interlocks with the groove 32 of the

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ring 28.

A further ring 38 fits inside each ring 34. The ring 38 has bores axially extending 40 through it at intervals around its circumference.

5 Dome-shaped end caps 42.1, 42.2 are secured by studs 44 to the rings 38, the studs 44 passing through the bores 40 and being screwed into tapped blind bores 46 (Figures 4 and 5) of the end caps 42.1, 42.2. The end cap 42.1 has two pipes 48 and 50 passing through it and the other end cap 42.2 has a single pipe 52 passing through it.

10 The order of assembly of the components of the end closure shown in Figures 4 and 5 is as follows. The end cap 42.2 is inserted into the end of the casing 12 and passes through the embedded ring 28. The ring 34 is then assembled inside the embedded ring 28 so that the rib 36 interlocks with the groove 32 and traps the end cap 42.2. The ring 38 is then inserted into the assembled ring 34 and the studs 44 passed through the ring 38 and screwed into the blind tapped
15 bores 46 of the end cap 42.2. The ring 38 expands the ring 34 and forces the rib 36 into the groove 32.

20 Water to be desalinated enters via the pipe 48 and flows into the space upstream of the left hand plate 22 as viewed in Figure 2. The water which emerges from the salt retention passages of the membrane 16.1 flows through the centre one of the plates 22 and into the membrane 16.2, and thereafter to the membrane 16.3.

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Brine emerges through the pipe 52 and permeated water emerges through the pipe 50.

The tube 18 is shown to a larger scale in Figure 6 which also illustrates two leaves 20 of the membrane. Two of the multitude of perforations, designated 54, in the tube 18 are shown. It will be understood that the perforations 54 are in rows along the tube 18.

The leaves 20 are of semi-permeable material which allows water to pass through but inhibits the transmission of dissolved solids. A spacer in the solids retention passage 56 is designated 58 and spacers in the permeate passages 60 are designated 62.

The membrane shown in Figure 6 is fabricated as illustrated in Figure 7. A web 64 of semi-permeable material is fed off a reel 66 and moved back and forth (left to right as shown in Figure 7) by a reciprocating head (not shown) so that the web is stacked in a zig-zag configuration thereby to form a plurality of layers designated 68, 68.1, 68.2, 68.3 etc in Figure 7. Tapes 70 are applied to the web 64 before it is stacked.

Before each layer 68 falls onto the stack the appropriate spacer 58 or 62 is inserted. The spacers 58 inserted from one side are spacers for the solids retention passages 56 and the spacers 62 which are fed in from the other side are spacers for the permeate passages 60 which have purified water in them. Each

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layer 68 is joined to the adjacent layer 68 by a reverse or "hairpin" bend. The bends are designated 72, 74.

At predetermined spacings, the transverse strengthening tapes 70 are secured to the web 64. The tapes 70 extend across the web in the direction of its width, that is in the direction of the length of the tube 18. The tapes 70 are best seen in Figure 6 and are applied by a head which moves in the direction of the length of the tube 18.

Adhesive lines are applied to both edge zones of the web 64 on those faces of the layers which bound the passages 60. Thus each passage 60 is closed along one edge by one of the left hand bends (designated 74) where the web 64 turns back on itself at the edge of the stack and along two other edges by the adhesive lines. Each passage 60 is open along its remaining edge, that is, along the edge which faces the tube 18.

The passages 56 which receive the water to be treated are open on three sides and closed along one side by alternate reverse bends (designated 72) in the web 64.

The inside edge of the stacked web 64 is opened out and the leading and trailing ends of the web are adhered to the tube 18 along two adjacent lines. A high percentage of the perforations in the tube 18 are thus in communication with the passages 60 of the stack. The stack at this time encircles the tube 18 and the

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leaves 20 protrude radially outwardly.

Once the leading and trailing ends are secured in this way, the stacked web is wound about the tube 18 as shown by the arrow A to form the membrane which is then slid into the casing 12.

5 As will clearly be seen, the strengthening tapes 70 are where the reverse bends 72, 74 are formed in the web 64 and prevent bursting of the wound membrane at the bends when water under pressure is fed into the casing 12.

To facilitate folding two sets of rollers 76.11 etc. and 76.21 etc. and two sets of rollers 78.11 etc. and 78.21 etc. are provided (see Figures 7 and 8).

10 The rollers 76.11 etc. and 76.21 etc. are on opposite sides of the web 64 to one another as shown in Figure 8. The rollers 76.11 etc. are vertically spaced from one another as are the rollers 76.21 etc. Each roller in the set 76.11 etc. is horizontally aligned with a roller in the set 76.21 etc.

15 Likewise the rollers 78.11 etc. and 78.21 etc. are on opposite sides of the web 64.

The rollers of the roller sets 78.11 etc. and 78.21 etc. are also vertically spaced from one another.

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When viewed in elevation (Figure 8) each roller of each set 78.11 etc. and 78.21 etc. is at a level midway between the adjacent rollers of the sets 76.11 etc., 76.21 etc.

Once the lowermost layer 68.1 of the web is in place, the lowermost rollers 76.11 and 76.12 are displaced inwardly to overly the edge portions of the web 64. The head which moves to lay down the layers 68.1 etc. then moves to the right (as viewed in Figure 7). The web 64 is thus pulled around the advanced rollers 76.11, 72.21.

Once the head has reached the end of its travel to the right in Figure 7, but before it reverses direction, the lowermost rollers 78.11 and 78.21 are advanced. Upon the head reversing, the web 64 is pulled against the rollers 78.11 and 78.21.

It will be understood that each time the head reaches the end of its travel in either direction, the next rollers of the sets 76.11 etc. and 76.21 etc., or the next rollers of the sets 78.11 etc. and 78.21 etc., are advanced.

This ensures accurate laying down of the layers.

It will be understood that the adhesive lines closing the edge zones of the web 64 can be applied inwardly of the rollers of the roller sets, as shown by lines 80 in Figure 8. Adhesive applying heads (not shown) can be provided between the reel 66 and the roller 82. Alternatively, the lines can be applied closer to the edges

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of the web as the rollers of the roller sets are withdrawn.

Whilst rotatable rollers are preferred, it is possible to use bars, preferably bars of circular cross section, against which the web is pulled by the head.

CLAIMS:

1. A spiral wound membrane which comprises an elongate web of a material which allows water to pass through but inhibits the passage of solids and/or dissolved solids and which has been folded to zig-zag form to produce a stack of layers joined to one another by reverse bends, a perforated tube, the ends of the web forming the stack being secured to the tube, said stack being wound around the tube, there being spacers between the layers, the spacers holding the layers apart to form water flow passages, alternate water flow passages having the ends thereof transverse to said bends sealed closed, said alternate passages being closed by reverse bends at the radially outer ends thereof and being in communication with the perforations of the tube at the radially inner ends thereof.

2. A spiral wound membrane as claimed in claim 1 and further including strengthening tapes which extend across the web coincident with said reverse bends, each tape extending on both sides of the respective bend.

3. A method of manufacturing a spiral wound membrane which comprises zig-zag folding an elongate web thereby to produce of a stack of layers with reverse bends in the web between layers, the web being of a material which allows water to pass through but inhibits the passage of solids and/or dissolved solids, inserting a spacer into the gap between each top layer of the stack and the layer which is being placed on it, said spacers being inserted alternately from opposite sides of the stack, attaching the free ends of the top and bottom layers of the stack to a perforated

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tube, and winding the stack about the tube.

4. The method as claimed in claim 3 and including the further step of applying adhesive along the edges of the web so that alternate gaps are closed along those edges of the stack which are transverse to the bends.

5. The method as claimed in claim 3 or 4 wherein, to strengthen the web, tapes are adhered to it, the tapes extending in the direction of the width of the web and being spaced apart at intervals which are such that, when reverse bends are created in the web during folding and stacking, it is the parts of the web to which the tapes are adhered that have said bends formed in them.

6. The method as claimed in claim 3, 4 or 5, and comprising reciprocating a head back and forth in the direction of the length of the web and feeding out the web from the head to lay down successive layers.

7. The method as claimed in claim 6 and including the step of advancing bars from opposite edges of the web to overlay that layer which is for the time being the top most layer and displacing the head in the reverse direction to pull the web against the bars which have been advanced.

8. The method as claimed in claim 7, wherein said bars are in the form of rotatable rollers.