June 25, 1946. W. R. P. DELANO 2,402,737

PROCESS AND APPARATUS FOR DISTILLING LIQUIDS

Filed Nov. 12, 1942 2 Sheets-Sheet 1

FIG. 1.

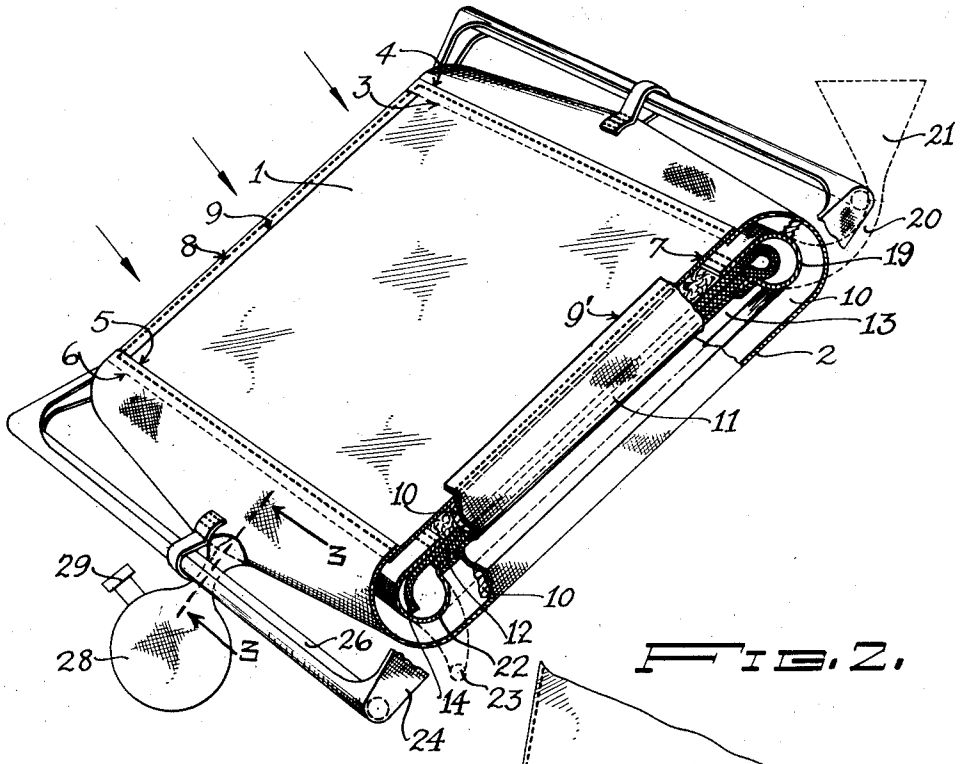


FIG. 2.

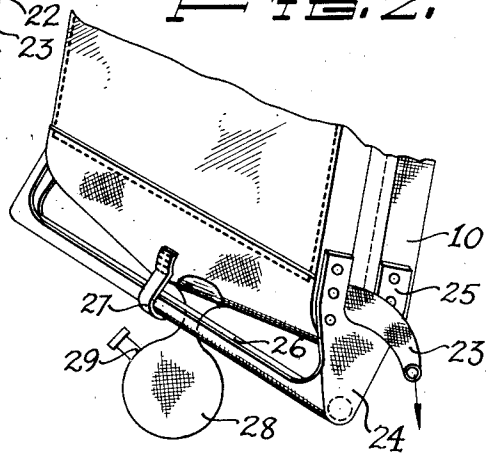


FIG. 3.

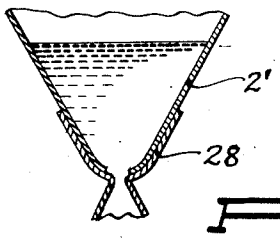
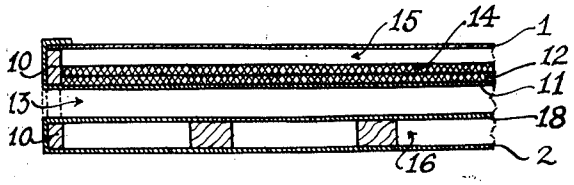


FIG. 3A.



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FIG. 4.

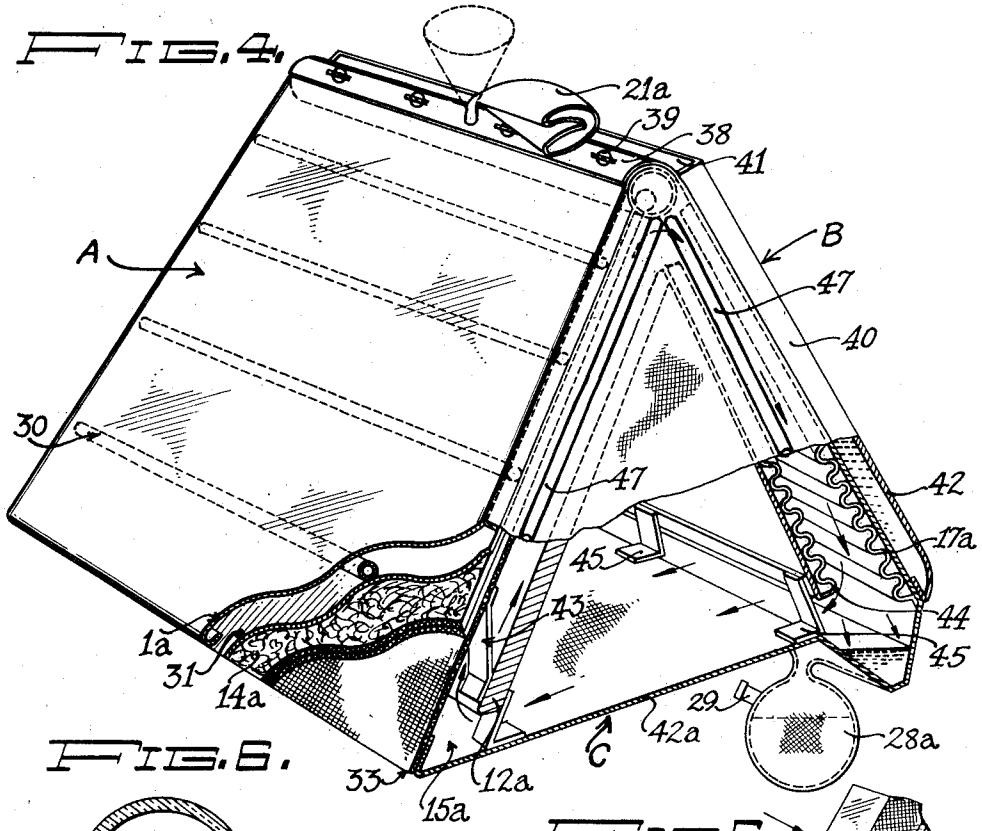


FIG. 6.

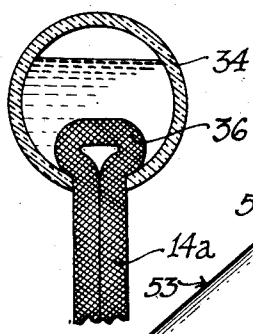


FIG. 7.

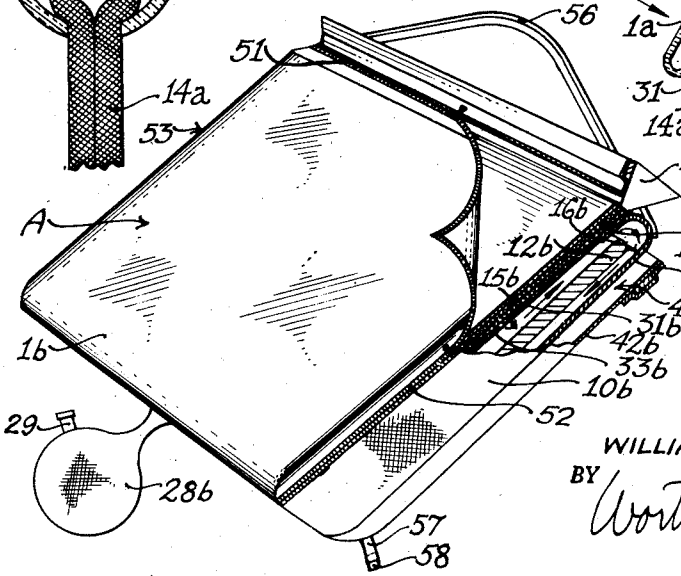


FIG. 5.

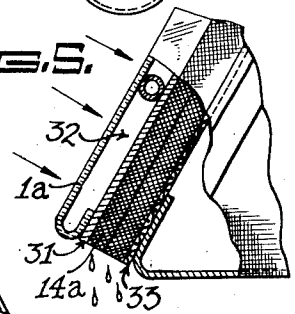
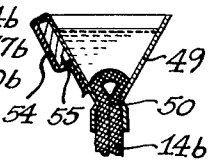


FIG. 8.



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Patented June 25, 1946 2,402,737

UNITED STATES PATENT OFFICE

2,402,737

PROCESS AND APPARATUS FOR DISTILLING LIQUIDS

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Application November 12, 1942, Serial No. 465,366

7 Claims. (Cl. 202—39)

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This invention relates in general to distillation and in particular to a process and apparatus for distilling salt water, in particular, sea water, and to correlated improvements designed to render such an apparatus collapsible and portable.

The need of a simple and convenient method of distilling sea water for the production of fresh water for drinking and the like has long been recognized, but this need becomes increasingly important during times of war when the destruction of ships and airplanes at sea forces the crews to take to lifeboats, rafts and rubber floats. In such small lifesaving craft it is apparent that space is limited, methods of heating either nonexistent or difficult to provide and all weight must be reduced to a minimum. Accordingly, any apparatus for distilling sea water to produce fresh water for drinking on lifesaving craft must meet, inter alia, the following stringent requirements.

1. The device must have a relatively low weight per unit of capacity. For example, when the apparatus is to be carried in aircraft and is to be used in a small rubber boat adapted only to carry two men, the weight of the distilling device should not exceed about twelve pounds and the capacity should be about two quarts per day.

2. Equally important as the weight is the space limitation involved in the transportation and in the use of the apparatus. The device must be compact and occupy a small space when not in use, i. e., when it is carried in an airplane, and when in use, it must be capable of efficient operation without occupying the space which would otherwise be available for an occupant of the lifesaving craft.

3. The device must be resistant to corrosion by sun, air, water and the action of the salts contained in sea water. It must also be fabricated of such material as will resist the rough handling incident to setting up and operating the apparatus under adverse weather conditions in crowded lifesaving craft.

4. The device should be capable of being erected without tools and by unskilled persons, and should be simple in operation.

5. The apparatus should be capable of being fabricated without the use of critical or scarce war materials, such as metals, plastics and the like.

6. The device should operate upon a source of cheap, plentiful fuel without the use of an open flame which would create a fire hazard. It has long been realized that a plentiful source of fuel at sea is solar radiation for, under the most adverse weather conditions, there will be,

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on the average, several hours of sunlight per day in those areas of the ocean which are navigable and free from ice.

Accordingly, it is the general object of the present invention to provide a process and apparatus for the distillation of liquids, in particular, sea water which will satisfy the objects above described and meet the specifications recited.

It is a further object to provide a process of distilling salt water by the use of solar radiation.

It is a specific object of the invention to provide a simple means for distilling sea water which is adapted for use on small lifesaving craft.

It is a further specific object to provide an apparatus for distilling sea water which will be collapsible, compact and light in weight, so that it can be carried in airplanes and installed as regular equipment in small lifesaving craft.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

According to the present invention, there is provided a process for distilling liquids, especially for distilling sea water for the production of fresh water, comprising saturating a layer of an absorbent material with the liquid to be distilled, heating the layer of absorbent material by solar radiation, evaporating liquid from a surface of the layer and condensing the evaporated liquid. The liquid may be evaporated from one or both surfaces of the absorbent layer.

The invention also includes an apparatus for distilling liquids, in particular sea water, comprising, in combination, a layer of absorbent material, means for saturating the layer with the liquid to be distilled, means for exposing the layer to solar radiation and means for condensing liquid evaporated from the layer.

The invention accordingly comprises a process having the steps and relation of steps one to another, and an apparatus having the elements and relation of elements one to another as set forth in the following detailed description and the scope of the application of which will be indicated in the claims.

For a more complete understanding of the nature and the objects of the invention, reference should be had to the accompanying drawings in which,

Figure 1 is a perspective view of one embodiment of the distillation apparatus of the invention,

Figure 2 is another view of part of the apparatus of Figure 1,

Figures 3 and 3A are cross-sectional views of certain parts of the apparatus shown in Figure 1,

Figure 4 is a perspective view of a second embodiment of the distillation apparatus, and

Figures 5 and 6 are side elevations, in section, of a part of the device shown in Figure 4.

Figure 7 is a perspective view of a third embodiment of the device, and

Figure 8 is a view, in section, of the trough of the device shown in Figure 7.

In order to explain the essential elements of the apparatus and the mode of operation of the process, a detailed description first will be given of several embodiments before the general discussion thereof, but it is to be understood that the invention is not limited to these embodiments.

In the embodiment shown in Figs. 1, 2 and 3 the evaporation of the liquid takes place from the upper surface of the absorbent layer, i. e. the surface which is exposed to the sun's rays; in that embodiment shown in Figs. 4, 5 and 6 the evaporation may occur from under surfaces only, while in the device shown in Figs. 7 and 8 the evaporation is from both surfaces of the absorbent layer.

Referring to Fig. 1, the simplest embodiment of the apparatus comprises a front sheet 1 of transparent material, a back sheet 2 of flexible non-porous sheet material, e. g. fabric, the back sheet extending on a curve over the top and having its edge 3 extending under, and being sealed to, the top edge 4 of the front sheet 1. The bottom of the sheet 2 extends around the bottom and has its edge 5 extending over, and being sealed to, the lower edge 6 of the sheet 1, as shown in Fig. 1. The side edges 7 and 8 of the sheet 1 are sewn under the edges 9 and 9' of a sheet 11 of flexible waterproof material, e. g. fabric, which extends over the rigid side panels 10 of shape-retaining material, e. g. wood, and this sheet extends through the opening and around the opposite side panel to form a back. Inside the device, there is attached to the upper side of the sheet 11 a coextensive layer 12 of insulating material, which has a non-absorbent upper surface, and a layer 14 of absorbent material which in this embodiment is dyed or pigmented black to render it heat-absorbent. The space between the layer 14 and the transparent sheet 1 forms the evaporating chamber 15 which communicates with the condensing chamber 16 which is the space between walls 2 and 18 which extend around the side panels 10 and are sewn to each other over the panels.

The layer 14 is hemmed at the top between the folded sheet 19, one end 20 of which extends through the opening 13 of the side panel 10 and terminates in the collapsible funnel 21 made of waterproof flexible material, e. g. fabric. The lower end of the layer 14 is sewn between a folded strip 22 of waterproof flexible sheet material which extends through the opening 13 and terminates in a spout 23.

The side panels 10 give the device stability in two dimensions, that is through the depth and the length. To give stability in the third dimension there is provided at each end of the device a flexible strap 24 having Y-shaped ends 25 (see Fig. 2) attached by brads or otherwise to the ends of the side panels 10. The total length of the strap is such that when stretched, the space between the loops will be greater than the width of the device as shown in Fig. 2. Thus, to stretch the strap and thereby impart stability to the device, there is inserted inside the strap between the end loops a stiff batten 26 which tends to

stretch the device widthwise as shown in Figs. 1 and 2. In the center of the lower end of the device a second strap 27 passes around the strap 24 and the batten 26 to stretch the center downward so that any condensate will tend to collect in the depression so formed. At the lowest point of the bottom 2' (Fig. 3) there is attached a communicating bag 28 formed of waterproof sheet material which may be provided with a pouring spout 29.

To operate the device shown in Fig. 1, the liquid to be distilled, e. g. sea water, is introduced through the funnel 21, the water flowing down the channel formed by the folded strip 19 from which it is absorbed through the absorbent material 14 until this layer is saturated. During the operation water should be maintained in the channel of the folded strip 19 so that the layer 14 may be maintained in a saturated condition since this layer will act as a wick when the liquid is evaporated therefrom. Any excess liquid carried by the layer 14 will collect in the channel formed by the lower folded strip 22 and run out through the spout 23. To distill the liquid the device is so positioned that the transparent sheet 1 and therefore the layer 14 will be positioned normal to the sun's rays, that is perpendicular to such rays, whereupon heat will be absorbed by the layer 20 and the liquid evaporated therefrom. Part of the vapor will condense upon the under side of the transparent sheet 1 since this sheet will always have a temperature lower than that of the layer 14. The heated vapor will tend to rise and pass over into the condensing chamber 16 where further quantities of the vapor will be condensed. The condensed liquid will run down and collect in the depressed base and run into the bag 28 from which it may be discharged through the pouring spout 29. If the device shown in Fig. 1 has a transparent sheet which is one square foot in area, it will produce per day in average sunlight one quart of distillate. When the device is formed of lightweight fabric and wood as above described, such device will weigh about one pound.

If desired, the device shown in Fig. 1 may be provided with a long strap at the top adapted to be passed around the neck of a person and with a second strap attached to the base adapted to be passed around the leg so that when a person sits facing the sun, the device will be stretched by means of the straps in any desired position. However, the device may be positioned on the back of a person, in which case it is preferably spaced from the body by means of a life preserver or wad of clothing to avoid the body heating the condensing chamber 16.

Alternatively, a foldable rack of metal or wood for supporting the device in any desired position may be readily devised by anyone skilled in the art without transcending the scope of the invention.

In that embodiment shown in Figs. 4, 5 and 6, the device has a triangular cross-section and comprises a front section A, back section B, and a base section C. Generally speaking, the device is placed so that the front section A is exposed to solar radiation, the evaporation occurring in the front, the condensation occurring in back section B, while the distillate is collected in the base section C. The front section A comprises preferably an outermost sheet 1a of transparent material spaced by suitable means, such as the horizontal transparent tubes 30 from a non-porous sheet 31, so that an air space 32 is provided

therebetween. The sheet 31 is a heat-absorbing and heat-conducting non-porous sheet material, preferably black, which is attached at its longitudinal side edges to a coextensive sheet 33 of porous material, such as open mesh made of wire or fabric, the space between the layers 31 and 33 being occupied by a layer 14a of liquid-absorbing material, e. g. a pile fabric, the layer 14a being unattached to the sheets 31 and 33. The layer 14a is attached at its upper edge to a tube 34 of a shape-retaining resilient material, for example, vulcanized fibre. The tube 34 is provided with a longitudinal slot in the base through which the upper edge 35 of the layer 14a is passed, the layer 14a being restrained from slipping through the slot by folding the edge to form a hem 36. The tube 34 is closed at each end but is adapted to be filled with water through hole which is positioned under a collapsible funnel 21a made, for example, of fabric. The funnel 21a is sewn to a flap 38 which is secured to the side of the tube 34 by suitable means such as buttons 39.

The back section B of the apparatus comprises pocket 40 open at its upper end 41 and defined by the outer wall 42 and the back wall 17a formed of a corrugated fabric, the wall 42 extending around the side and being attached, as by sewing, to the edge and bottom of the wall 17a and to the base sheet 42a. In the interior of the device there is provided a layer 12a of insulating material, for example kapok, which is spaced from the sheet 33 of mesh to form an evaporating chamber 15a by means of the tape 43 of fabric, the layer 12a being of such dimension that a space is left at its upper and lower ends. If desired, a second layer of corrugated fabric 44 may be sewn at its top to the insulated layer 12a and its lower edge to the base sheet 42a by means of the fabric tape 45 so as to leave a space open at the bottom, thus defining a rear condensing chamber 16a. The base 42a is stitched to form a V-shaped trough 46 into which the condensed liquid may be collected. From this trough the liquid may be collected in the bag 28a formed of non-porous material having a pouring spout 29a.

Assuming that the apparatus is set up as illustrated in Fig. 4 and so positioned that the sun's direct rays are perpendicular to the front section A, the apparatus may be operated as follows:

The liquid to be distilled, such, for example, as sea water, is introduced through the funnel 21a while the funnel is positioned as shown in the broken lines. The liquid will distribute itself throughout the length of the tube 34 and thus wet the upper end of the absorbing layer 14a and gradually seep downward throughout the full extent of this layer. The solar radiation will heat the black sheet 31 and by conductance heat the liquid carried in the layer 14a, thus causing some of the liquid to evaporate from the under surface of this layer through the mesh sheet 33 which supports the layer 14a. The warm air carrying the vapor of the liquid will pass upward in the chamber 15a and the vapor will condense in the chamber 16a. To promote the condensation, the pocket 40 may be filled with cool water, e. g. sea water, through the open top 41. The distillate will collect in the trough and run into the bag 28a. The cool air containing some uncondensed water vapor will pass along the base 42a and will rise again in the chamber 15a. If the black heat-absorbing sheet 31 is formed of porous material, evaporation may occur from both surfaces of the layer 14a.

When the device is formed of a flexible non-rigid material, such as textile fabric, it is advisable to provide certain form-retaining elements to maintain the shape of the apparatus. Accordingly, side edges of the front section A and the edges of back section B may be each provided with a long pocket 47 into which a thin batten of stiff material, e. g. wood, may be slipped, the pockets being open at the bottom but closed at the top. The longitudinal collapse of the device is prevented by the stiff tube 34 which extends across the top as shown in Fig. 4.

A third embodiment of the invention is shown in Figs. 7 and 8 in which the front section A comprises a transparent sheet 1b, a layer 14b of liquid-absorbing material enclosed between a sheet 31b of heat-absorbing material and a sheet 33b of porous (mesh) material. The upper end of the layer 14b, e. g. pile fabric, is sewn to the bottom of a trough 49 of fabric so as to form a constricted area 50. The trough and the sheet 31b and layer 14b may be removed from the device for cleaning by means of slide fasteners 51 and 52 which extend across the top and along one side of the transparent sheet 1b. The bottom edge and the other side edge 53 of the sheet 1b are sewn to the back sheet 17b and to the side panel 10b, respectively. The side panels are rectangular or oval so that the back walls 17b and 42b which define a pocket 40b are substantially parallel with the front wall 31b. The layer 12b of insulating material serves to divide the interior of the apparatus into an evaporating chamber 15b and a condensing chamber 16b, space being allowed at each end of the insulating layer 12b to allow free circulation of the vapor between these chambers.

In the preferred embodiment of the device shown in Fig. 7, the side panels 10b are formed of shape-retaining rigid material such as stiffened fabric, hard vulcanized fibre, plywood or the like, whereby dimensional stability is given to the structure across and along such panels. To obtain stability in the third dimension (lengthwise of the trough) suitable pocket and flat stiff batten to fit therein are provided across the bottom edge, across the one wall of the trough 49 and across the top edge of the pocket 40b, as shown in Fig. 8. To collapse this device, the battens are removed, and the body collapsed and folded about one of the end panels. When the device shown in Figs. 7 and 8 is made so that the width is not more than three feet and the height not over two and a half feet, it may be provided with a strap 56 to go about the neck of a person. The device may rest either on the back or on the knees and chest of the person. A second strap may be attached to the base to go around the leg or waist. Thus, in a crowded life-boat or the like, the distillation apparatus will not occupy the space of an additional seat.

For operation, the person wearing the device has only to position the heat-conducting sheet 31b so that it is perpendicular to the rays of the sun. For distilling sea water, the trough 49 is filled with the sea water until the layer 14b of absorbent material is saturated, and the pocket 40b is kept filled with cold sea water. From the pocket 40b the warm water may be exhausted through the tube 57 which is provided with a plug 58. The distillate is collected in the bag 28b from which it may be discharged through spout 29, by squeezing the neck of the bag and turning the bag up.

In the preferred embodiment, all sheet mate-

rials employed in the apparatus are flexible sheets so that the apparatus may be collapsed and rendered compact for shipment or storage. When the battens are removed, the back section 11 may be collapsed against the front section 10 and the two sections rolled upon each other starting with the top so that the tube 21 forms a supporting core for the roll. The rolled apparatus may be encased in a container or carrying case of suitable type, not herein illustrated.

The sheet 1 of transparent material shown in the apparatus of Fig. 1 should be a flexible but form-retaining sheet of any suitable transparent hydrophobic material, such, for example, as a cellulose ester, a cellulose ether, or a synthetic resin. Preferably, there is employed for this sheet material a transparent plastic which is permeable to visible and infra-red radiation such, for example, as cellulose acetate or cellulose aceto-butyrate. It is to be understood that the transparent sheet shown in Fig. 4 is employed solely for trapping a layer of warm air next to the surface of the heat-conducting layer 31. When evaporation takes place only from the underside of the layer 14, the transparent sheet may be omitted.

For the heat-conducting layer 31*a* or 31*b* there may be employed any one of the following:

(*a*) A thin sheet of material which is capable of being rolled upon itself and which may be formed of copper, brass, nickel, aluminum and other non-corrosive metals.

(*b*) A layer of nonporous textile fabric preferably a layer of closely woven fabric which has been dyed black or impregnated with carbon black which renders it heat-absorbing. When this fabric layer is to be non-porous, it is preferably sized or coated with a waterproofing composition comprising a resin, a cellulose derivative, wax, rubber, etc.

(*c*) A layer of textile fabric formed in whole or in part of metallic fibres or yarns by which its heat conductivity is increased. In other respects this layer should have the characteristics enumerated under "*b*."

For the layer 14 of absorbent material, there may be employed a layer of pile fabric, a layer of inter-felted fibres such, for example, as textile felt or a soft, porous paper which has been sized with a water-insoluble substance such, for example, as casein, a resin or a cellulose ester which does not disintegrate when wet. Since layer 14 should be capable of being washed and wrung out, it is preferably formed of a material having a sufficient tensile strength for this purpose, that is, a textile fabric or felt.

For the sheet 33 of porous mesh material, there may be employed an open mesh textile fabric formed of high tensile yarns or a mesh of woven non-corrosive wire. Since the layer 14 of absorbent material, when saturated with water, will be almost wholly supported by the sheet 33, this sheet must be of such strength as to support the weight of the layer 14.

The sheet 12 of insulating material may be formed of felt, paper, viscose sponge, spun glass or rock wool, or any other suitable flexible insulating material. The upper surface of the layer 12 which will be exposed to the heated vapor should be rendered non-absorbent as by coating the surface with an hydrophobic cellulose ester, cellulose ether, synthetic resin and the like.

All other parts of the apparatus, such as the base sheet 42 and back walls may be formed of any flexible non-porous sheet material such, for example, as textile fabrics, felt or paper. Such materials should be stiffened and rendered waterproof by impregnating or coating them with an hydrophobic cellulose ester, cellulose ether, synthetic resin and the like. In general, all such sheet materials should be water impermeable. However, to promote the cooling of the water held in the pocket 40, the wall 17*a* may be made of a porous material so that water will evaporate from its surface.

It is understood that various changes can be made in the apparatus and in its mode of operation. In particular, for stabilizing the shape of the device when it is made largely of flexible non-rigid material, suitable folding frames of wire or wood may be readily devised by those skilled in the art without transcending the scope of the invention. More or less permanent frames may be readily devised from flag poles, lances, bayonets, rifles, boat hooks and other available rigid members. To facilitate the use of such framing elements, the device is preferably provided with strong cords or tapes 52 sewn at the corners so that the device may be stretched upon the rigid frame. It is obvious that the device is not limited to any particular size, nor is it limited to use at sea or in life-saving craft, but may likewise be used in the desert or anywhere for the distillation of non-potable water of all kinds.

Accordingly, the present invention provides for the first time a light-weight portable distillation apparatus which can be fabricated free of scarce metals and plastics so that the weight per unit of capacity can be kept extremely low, for example, to less than 2 pounds per quart of liquid distilled in 12 hours. The present device is small in size, readily collapsible to a compact unit and easily reconstructed without tools or mechanical skill. The device is especially adapted to be carried in aircraft as a part of the regular equipment of emergency life-saving rafts or floats. Since it may be fabricated of tough fabric or paper and the like, it is resistant to corrosion and withstands rough handling. The fact is that it requires no solid, gaseous or liquid fuel, it is economical to carry and operate and does not create a fire hazard in storage or use.

Having described my invention, what I claim as new and desire to secure by Letters Patent is:

1. Apparatus for distilling liquids by solar radiation, comprising an absorbent layer of material movable into a position normal to the sun's rays, a container extending along the upper edge of said layer and formed with a slot therein into which said absorbent material extends to receive liquid from the container, and means for conducting vapor from said absorbent layer to an area shaded from the sun's rays for condensing said vapor.

2. In solar distillation apparatus an enclosure formed of flexible material and having a flexible window therein, a layer of flexible absorbent material located within said enclosure and connected thereto, means for supplying liquid to be distilled to said layer, rigid members connected to said enclosure, and extending along opposite edges thereof, and means for holding said enclosure and absorbent material extended for use including elements extending from one of said rigid members to the other and of such length as to place said enclosure under tension from side to side when in place, said elements being separably connected to said rigid members and

to said enclosure, whereby said apparatus may be collapsed for storage.

3. In solar distillation apparatus, an enclosure formed of flexible material and having a flexible window therein, a layer of flexible absorbent material located within said enclosure and having its edges connected thereto, members connected to said layer and enclosure and located adjacent opposite edges thereof, said members being rigid and serving to hold the edges of the enclosure and the layer of material in spaced relation, and means extending from one of said members to the other and of such length as to place said enclosure and layer of absorbent material under tension whereby the window in said enclosure will be held in spaced relation with respect to said layer of absorbent material when the apparatus is in use, said means being separable from said members to permit the apparatus to be collapsed for storage.

4. A method of distilling liquids whch comprises the steps of supplying a liquid to be distilled to a layer of absorbent material exposing one face of said layer to solar radiation, condensing vapors issuing from the opposite face of said layer, and separating the resulting condensate from the liquid being distilled.

5. Collapsible solar distillation apparatus comprising a layer of flexible absorbent material presenting opposite liquid retaining faces, means for supplying liquid to be distilled to said layer, flexible means forming an enclosure extending about said layer, said enclosure having at least a portion thereof which is transparent and through which one face of said layer may be exposed to solar radiation, said enclosure including condenser surfaces supporting means moveable to an extended position for holding said enclosure and said layer in an operable position spaced relation wherein said enclosure is spaced from the opposite faces of said layer, said supporting

means being movable to a collapsed position in which said enclosure and layer are foldable into a compact inoperative position, and collecting means separated from the liquid supplied to said layer and communicating with the space between said enclosure and both faces of said layer for receiving liquid condensing on the condenser surfaces of said enclosure when said supporting means is in said extended position.

6. Solar distillation apparatus comprising a collapsible fluid proof enclosure, presenting condensing surfaces a layer of absorbent material within said enclosure, means for supplying liquid to be distilled to said layer of absorbent material, a transparent flexible window in said enclosure, through which the heat of the sun may reach said layer of absorbent material means forming a dead air space in heat transferring relation between said window and one face of said layer of absorbent material, and means on the opposite side of said layer of absorbent material for receiving and separately collecting condensate formed on said condensing surfaces from vapors issuing from said layer.

7. Solar distillation apparatus comprising a layer of absorbent material presenting opposite liquid retaining faces, means for supplying liquid to be distilled to said layer, means forming a collapsible enclosure extending about said layer, said enclosure having at least a portion thereof which is transparent and through which one face of said layer may be exposed to solar radiation, and a portion which acts as a condenser means for holding said enclosure when not collapsed in spaced relation to the opposite faces of said layer, and collecting means separated from the liquid supplied to said layer and communicating with the space between said enclosure and both faces of said layer for receiving liquid condensing on the condenser surfaces of said enclosure.

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