

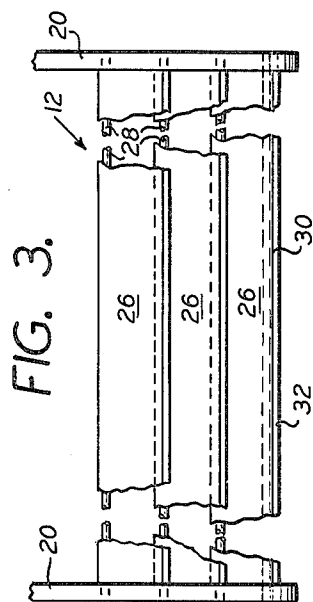
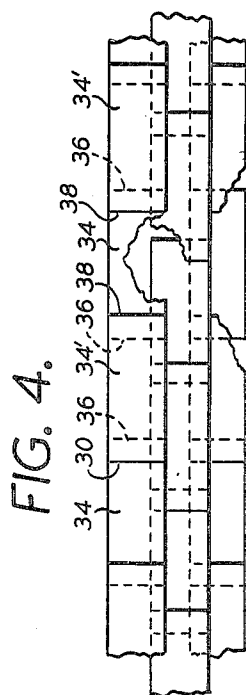
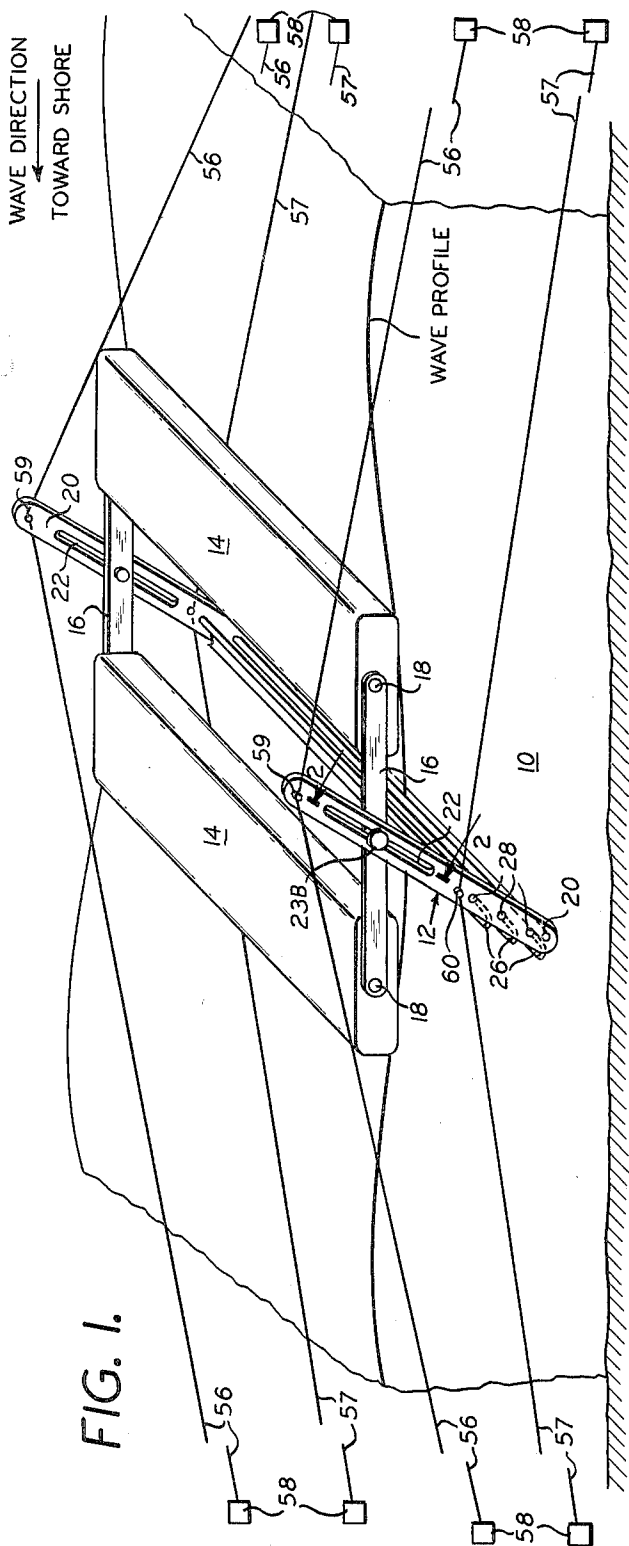
Dec. 14, 1965

H. F. MILLER ET AL
METHOD AND APPARATUS FOR TRANSPORTING MATERIAL
IN A LIQUID HAVING WAVE PROPAGATION

3,222,871

Filed May 4, 1962

5 Sheets-Sheet 1



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FIG. 2.

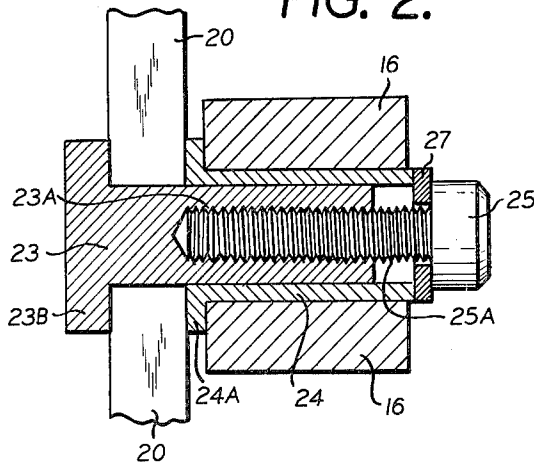


FIG. 7.

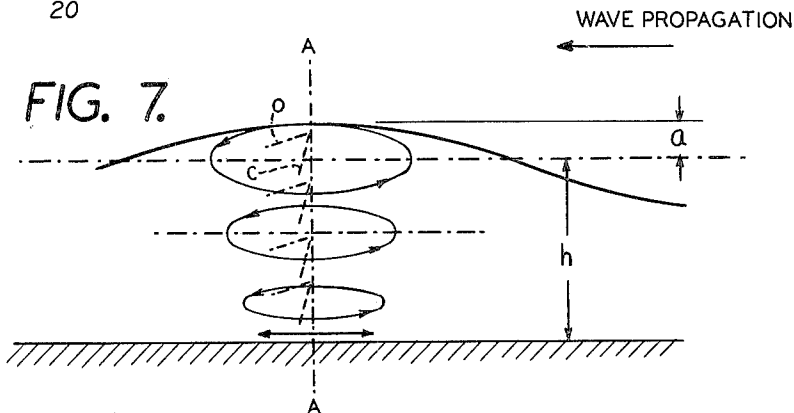
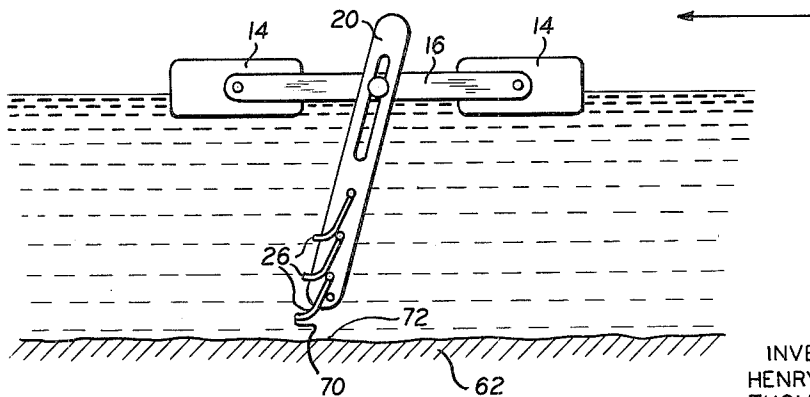


FIG. 8.



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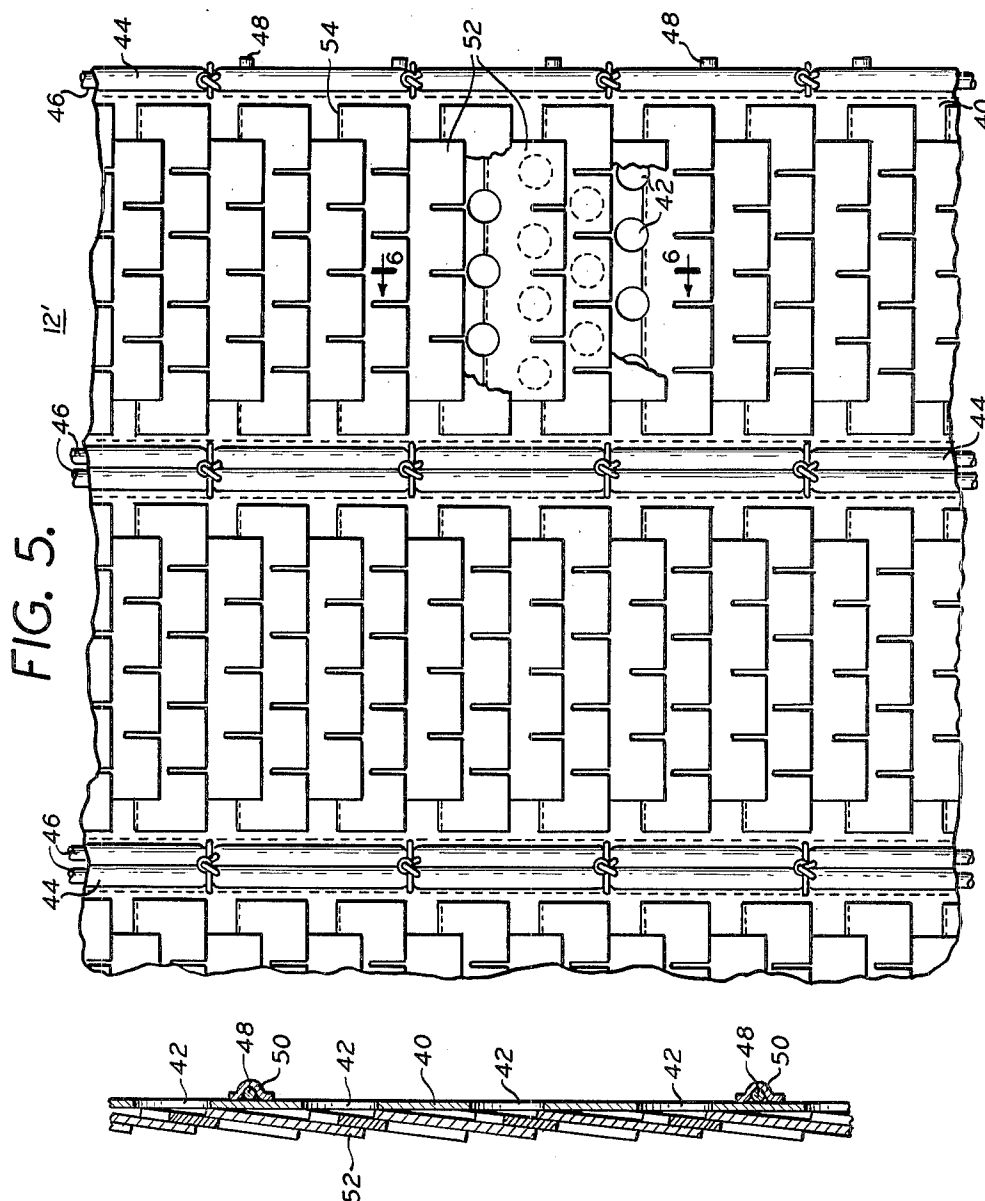
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5 Sheets-Sheet 3



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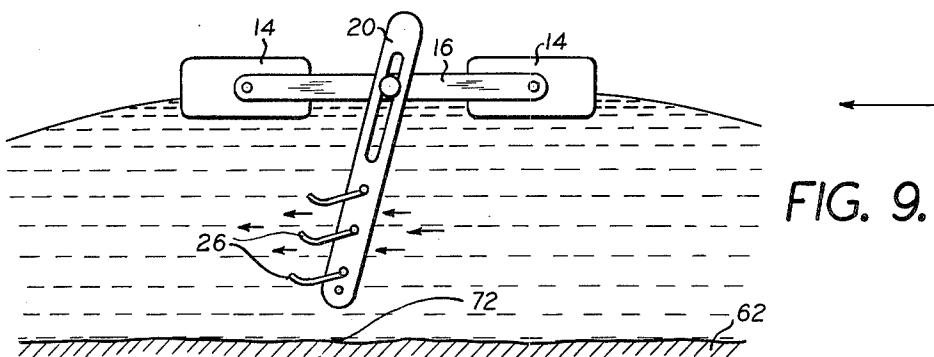


FIG. 9.

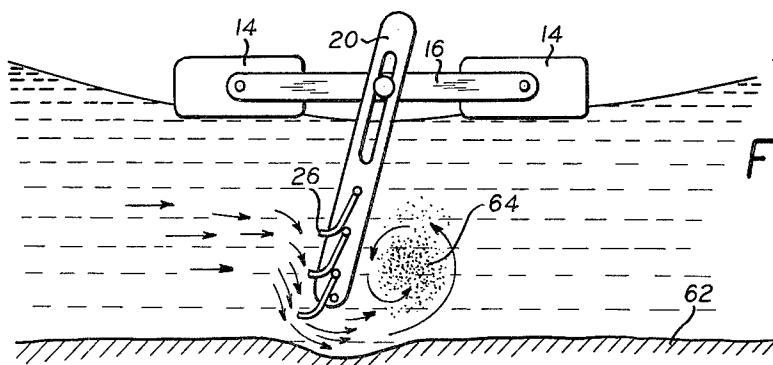


FIG. 10.

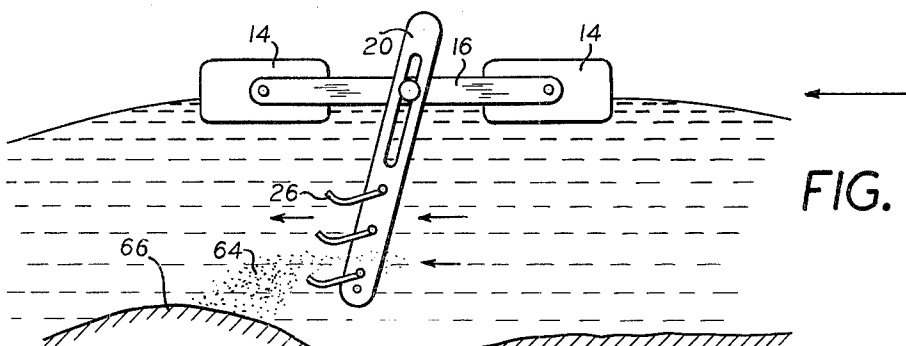


FIG. 11.

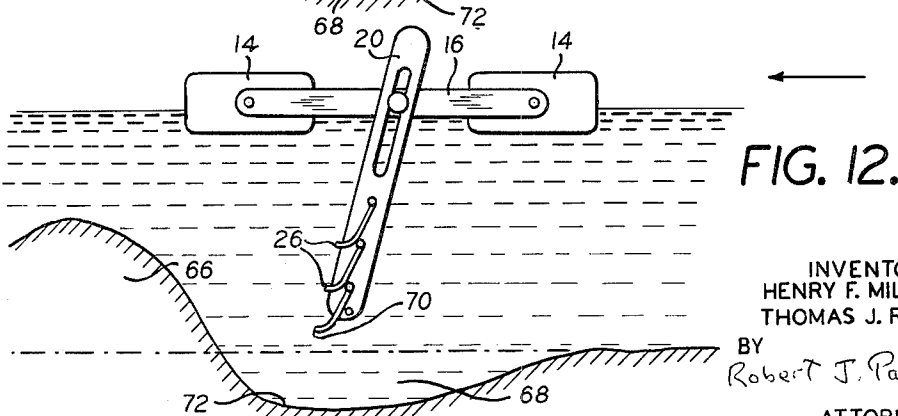


FIG. 12.

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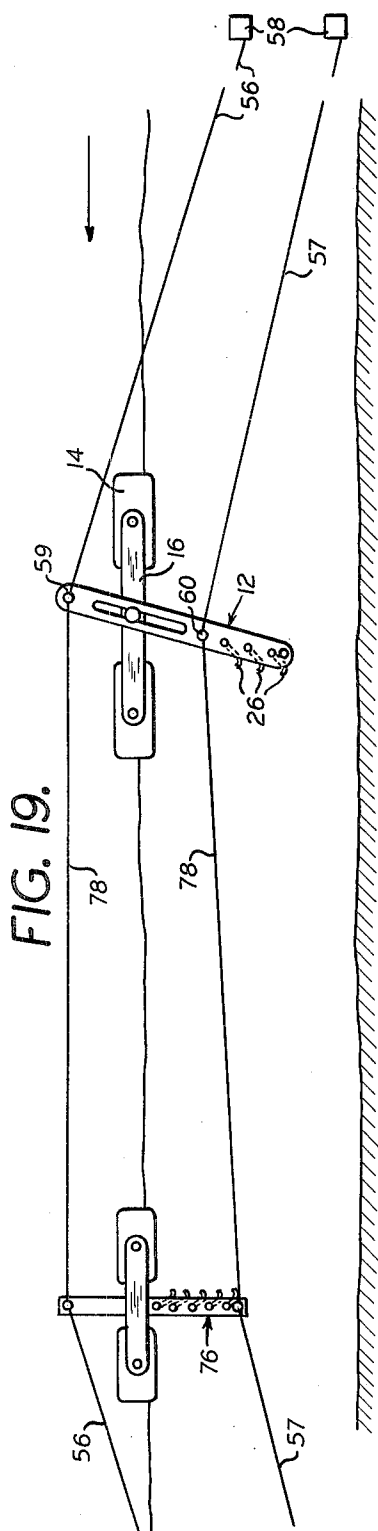


FIG. 13.

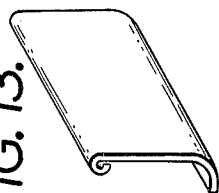


FIG. 14.

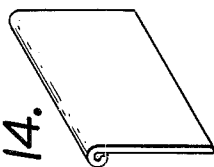


FIG. 15.

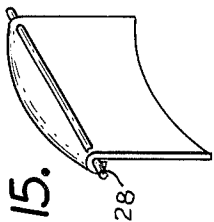


FIG. 16.

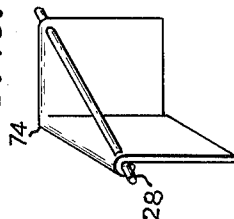


FIG. 17.

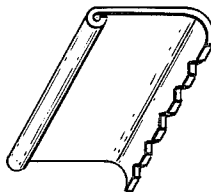
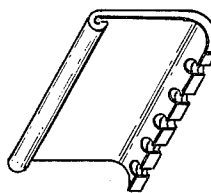


FIG. 18.



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METHOD AND APPARATUS FOR TRANSPORTING MATERIAL IN A LIQUID HAVING WAVE PROPAGATION

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Filed May 4, 1962, Ser. No. 192,504
3 Claims. (Cl. 61—5)

This is a continuation-in-part of application Serial No. 178,842.

This invention relates to a method of dredging and to an apparatus therefor. More particularly, this invention relates to a novel device for dredging solid materials located in a bed beneath a liquid, which device utilizes the energy associated with waves propagated in the liquid to sustain its dredging action.

Heretofore numerous attempts have been made to devise dredging devices whereby large bodies of material beneath a liquid can be transported to desired locations. Numerous means have been employed heretofore to accomplish this end such as, for example, pump-actuated pipelines, motor-driven dredging buckets, etc.

However, heretofore none of the various prior-art techniques has been fully satisfactory. Thus, generally prior-art dredging devices have been massive and unwieldy so that it has been difficult and expensive to transport such devices. Further, such prior-art devices have been extremely expensive to operate because of the very high power requirements. In addition, the dredging operation can be severely hampered by wave action.

Other dredging devices have been suggested heretofore, which devices rely upon the energy associated with waves to sustain their dredging action. Reference is particularly made to U.S. patent application Serial Number 89,174, filed February 14, 1961, which application relates in part to such a dredging system. The device utilized comprises horizontal float means and horizontal brake means spaced beneath the float means and provided with a plurality of valves to resist rising through a liquid in which waves are propagated. Wave energy is transmitted from the float means to the brake means, which transmission will, under appropriate conditions, also result in dredging, i.e., provided that the brake means are disposed near the bed beneath the liquid. Although this horizontal type of dredging device has been effective, it has been felt that improved devices could be obtained.

Reference is also made to our U.S. patent application Serial Number 178,842, filed on March 12, 1962, entitled "Apparatus and Method," describing a novel apparatus and method for attenuating liquid waves, and utilizing a system of vertical baffles to effect such attenuation. Certain aspects of the apparatus described herein are related to the construction of the apparatus described herein and, accordingly, the contents of such application are hereby incorporated by reference into the present application.

The apparatus described in our aforesaid U.S. patent application Serial No. 178,842 comprises two end baffles and at least one intermediate baffle, means for floatably suspending the baffles substantially vertically in a wave-containing liquid, and means for anchoring the baffles. Each of the baffles is valved to permit liquid flow there-through in one direction only, and the end baffles are valved to open toward one another. As will be seen, certain of these features are also employed in the present application.

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It is apparent that a dredging device which is of simple construction, is economical to operate, and can transport large quantities of solid material from one location to another, is highly desirable. Such a device could be used where constant beach erosion is a serious problem. For instance, such a dredging device could be installed offshore so as to "nourish" the beach by continually supplying sand to the beach area. Such build-up would compensate for any loss of beach sand that would otherwise occur due to the forces of erosion generated by the action of the waves as they beat upon the shoreline. In addition, such a dredging device could be used to dredge channels, to build up artificial sandbars offshore so as to thereby provide a bathing area that is shielded from the action of breakers from the sea, etc.

Accordingly, it is an object of our invention to provide a novel method for dredging material.

Another object is to provide a unique device to effect such dredging.

A further object is to provide a novel dredging device, which device is actuated by energy associated with waves in the liquid in which the device is suspended.

Yet another object is to provide a dredging system which is economical to produce and to operate and which can be used to transport material beneath a liquid from one given location to another.

Additional objects will become apparent hereinafter.

The foregoing objects are achieved by the use of a dredging device of special construction. The device utilizes a baffle or series of baffles. The baffle is suspended in the liquid in which the waves are propagated, and generally is disposed either vertically or is inclined at a suitable angle, depending upon the geometry of the bed beneath the liquid, the amount of material to be transported, the desired situs for deposit of the material, etc.

In accordance with our invention, the baffle is so designed and valved that it will permit the passage of liquid, e.g., water, therethrough in one direction only. The baffle is floatably suspended in the liquid with the face of the baffle being disposed transversely of the direction of wave movement. The disposition of the baffle in the liquid is such that the valving thereof permits passage of the liquid from the seaward side therethrough and toward the shore but does not permit passage of liquid from the shoreward side therethrough and towards the seat. Floating means are provided for the baffle so as to insure that the baffle will be floatably suspended in the liquid. In addition, anchoring means are provided on both the seaward and shoreward sides of the baffle so as to maintain the baffle in a selected orientation within the liquid, e.g., vertically disposed within the liquid, or inclined in the liquid at an appropriate angle.

Where long-period shallow-water waves occur, i.e., wherein the ratio of wave length, λ , to mean water depth, h , is very high ($\lambda/h \gg 1$), the orbital path of the water becomes highly elliptical; that it, it follows the shape of an ellipse whose major axis is horizontal. This results in a condition where the water is moving toward shore and away therefrom in an essentially horizontal pattern. As a result of this elliptical configuration, the water advances horizontally toward the shore at the crest of the wave and moves seawardly at a point one-half wave length away. The horizontal velocities within the wave at these two points are substantially the same but the motions of the water are in opposite directions.

Our dredging device is so constructed that when the crest of a wave passes through the baffle and toward the shore there is virtually no obstruction to the liquid flow. However, when the wave trough encounters the baffle

(one-half wave length later), the direction of liquid flow is seaward rather than shoreward, and the valves of the baffle are closed. The closed valves prevent liquid from passing therethrough and actually deflect the liquid so that it flows downward, beneath, and seaward of the baffle. Provided that the bottom of the baffle is appropriately spaced from the bed of material beneath the liquid, this downward liquid flow will cause severe agitation of such material and will actually induce a lifting from the bed of relatively large quantities of material and will maintain such material in suspension. As the next wave crest advances toward the shore, the baffle valves are opened so that no impairment to liquid flow shoreward is offered, and as the liquid flows through the baffle it also transports through the baffle those particles of bed material which have been agitated and are in suspension, thereby effecting a net transport shoreward of such particles.

For a more complete understanding of the nature of our invention, reference may be had to the following detailed description, taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is a perspective view of one embodiment of our dredging device, which device comprises a baffle floatably suspended within a wave-containing liquid;

FIG. 2 is a vertical cross-sectional view taken along the line 2—2 of FIG. 1;

FIG. 3 is a partial elevational view of the baffle and shows the panels and mounting therefor;

FIG. 4 shows an alternate construction and is a partial elevational view of a baffle wherein each panel is made up of overlapping components;

FIG. 5 shows another alternate construction and is a partial elevational view of one of the baffles wherein a plurality of holes are provided, with valve flaps for each hole;

FIG. 6 is a cross-sectional view along the line 6—6 of FIG. 5;

FIG. 7 is a schematic, longitudinal, cross-sectional view through a long-period wave;

FIGS. 8—12 are schematic profile views of our dredging device and show its operation as a wave passes therethrough;

FIG. 13 is a perspective view of one embodiment of a panel used in our baffle and shows a curvature at the lower edge thereof;

FIG. 14 is a perspective view of another embodiment of our panel wherein there is no curvature, the panel being planar;

FIG. 15 is a perspective view of another embodiment of our panel wherein the panel is curved transversely;

FIG. 16 is a perspective view of another embodiment of our panel wherein two portions thereof converge at the center of the panel;

FIG. 17 is a perspective view of a further embodiment of our panel wherein the lower edge is provided with a series of V-notches;

FIG. 18 is a perspective view of yet another embodiment of our panel wherein the lower edge is provided with a series of apertures having helical ridges therein; and

FIG. 19 is a schematic profile view of another embodiment of our invention wherein an oppositely valved baffle is employed along with the dredging baffle.

One embodiment of our invention is shown in FIG. 1, wherein our dredging device is generally designated by the reference numeral 10. The dredging device comprises one or more baffles 12, such baffle shown suspended in the water by means of buoyant floats 14. As shown in FIG. 1, a pair of floats 14 are provided for the baffle 12, one such float 14 being on either side of the baffle. Each such float 14 is pivotally mounted on horizontal supporting member 16 by means of pivot pin 18 which extends through both supporting member 16 and float 14. Supporting member 16 is pivotally mounted on inclined member 20, which member 20 is provided with

a slot 22 whereby the relative depth of baffle 12 beneath the water can be controlled and adjusted.

Referring to FIG. 2, which is a cross-sectional view taken along the line 2—2 of FIG. 1, means are shown for pivotally mounting floats 14 on inclined member 20. These means include flanged cylinder 23, flanged sleeve 24, screw 25, and washer 27. Flanged cylinder 23 bears internal threads 23A. Flanged sleeve 24 is slidably mounted on the cylindrical portion of flanged cylinder 23. Screw 25 contains external threads 25A which engage with matched internal threads 23A. In order to firmly clamp supporting member 16 to inclined member 20 at a selected position in slot 22, screw 25 is simply tightened, whereupon washer 27 is biased against sleeve 24 so that flanges 24A and 27B are forced toward one another and hence tightly grip inclined member 20 at the edges of the slot.

Baffle 12 contains one or more rectangular panels 26, each of which is pivotally mounted to a substantially rigid member 28, e.g., a tube, rod or the like, which extends transversely of the dredging device 10. It will be seen that members 20 in conjunction with transverse members 28 defined a "grid" type structure, as shown in FIG. 3.

Panels 26 may conveniently be made of a relatively rigid or stiff material, certain types of plastics being particularly suitable, e.g., plastic sheetings or moldings made of "ABS polymer," e.g., a blend of rubbery butadiene-acrylonitrile copolymer with resinous styrene-acrylonitrile copolymer as disclosed in U.S. Patent No. 2,439,202, graft polymers formed by grafting styrene and acrylonitrile onto polybutadiene, etc.

Such panels 26 are desirably molded so as to have a cavity at the top thereof, through which cavity extends member 28 (FIG. 3). This method of securing panel 26 to member 28 insures a freely pivoting action whereby the panel will readily respond to any water motion. In order to promote a prompt response, e.g., a "snapping" action downward, of the panel 26, e.g., when a wave trough is passing, there may be secured to the bottom (free) edge 30 of each such panel a weighted strip 32.

Where the width of our dredging device is relatively great, the construction shown in FIG. 4 may be used, wherein several panel segments are utilized rather than single panel 26. In this construction, successive panel segments are alternately overlapped and underlapped so that the vertical edges 36 of a given panel segment 34 are overlapped by the edges 38 of adjacent panel segments 34', etc. Successive rows of panel segments can be staggered as shown.

In general, the baffles should offer, in their "open" position, the maximum possible void area for passage of liquid therethrough, so as to give our device an overall efficiency. From a consideration of FIGS. 1 and 3, it will be seen that when the panels 26 of a baffle are displaced outward by the action of a wave, the void area approaches 100% since the only impediments to liquid flow are the members 28 on which the panels are mounted, the panel material disposed therearound, and the submerged portions of the float system and of inclined members 20. Accordingly, the efficiency of the system is virtually the optimum attainable. Since each panel 26 is itself a thin strip of substantially rigid material, it will readily hinge and pivot away from its "stop" position when any force is exerted on it by a liquid pressing against it in a direction to swing or pivot the panel 26 away from the member 28 on which the lower (free) edge 30 of the panel rests and overlaps. However, when the liquid flows in the opposite direction, it forces the panel 26 to pivot downward to a position such that its lower (free) edge overlaps and presses against member 28, so that when all the panels 26 are in such position the baffle is closed.

In accordance with another embodiment of our invention, a baffle 12' may be substituted for paneled baffle 12. Each such baffle 12' comprises a sheet 40 provided with a

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multiplicity of holes 42 therethrough (FIGS. 5 and 6). Preferably, the sheet 40 is made of segments of coated fabric of convenient length. At each side the perforated sheet 40 is folded over and secured, e.g., cemented, heat sealed, or stitched to itself, to form a pocket 44 in which is placed a member 46 which may be rigid, e.g., a rod, or flexible, e.g., a cord or the like. As shown in FIG. 5, the adjacent rods 46 in adjacent pockets 44 are butted and tied together.

In order to impart transverse reinforcement to the sheet 40, a plurality of rods 48 are mounted horizontally to the sheet so as to form a grid-type structure with rods 46. As shown in FIGS. 5 and 6, each such rod 48 passes through a pocket 50, and also is secured to rods 46.

Although the perforated baffle 12' is made from a material impervious to water, it is provided with a multiplicity of holes 42 therethrough, in order to enable the water to pass therethrough.

Additionally, means are attached to each baffle 12' to enable the baffle to restrict passage of water therethrough in one direction, but to permit the water to flow readily through each baffle in the opposite direction. These means may desirably comprise flapper strips 52 which are arranged to overlie holes 42 at least partially. In the embodiment illustrated in FIGS. 5 and 6, flapper strips 52 are narrow rectangular strips of coated fabric which cover holes 42 completely in a shingle-like fashion. Each flapper strip is attached along its upper edge 54, as by heat sealing, stitching, or the like to the perforated baffle, while the sides and the lower edge are left free.

Since the flapper strips 52 are themselves thin flexible sheets of coated fabric, they will hinge and bend away from the perforated baffle when any force is exerted on them by liquid passing through the holes in a direction that lifts the strips 52 away from the perforated sheets; when the liquid moves in the opposite direction, it will force the flapper strips 52 flat against the perforated sheets, thereby to close the holes therein. Thus, each of the thin flexible flapper strips 52 is affixed along an upper edge 54 to the baffle and is adapted to overlie a hole 42 when arranged flat against the sheet.

Referring again to FIG. 1, floats 14 are attached to the baffle at some point above the panels 26 and thereby maintain the baffle suspended in the water in an inclined or in a vertical position. Any suitable floating means may be employed. For example, each float 14 may simply be a large, sealed container. Alternatively such float may be made of an imperforate, unicellular, e.g., closed-cell, expanded elastomer having a specific gravity less than one.

The buoyance provided by the float must be sufficiently great that the baffle supported thereby will "follow" the vertical wave displacement virtually instantaneously. This is best attained by designing the float to cover a relatively large water surface area as shown in FIG. 1.

Means to anchor the baffle on both the seaward and shoreward side are provided. The anchoring means desirably comprises an array of long tie ropes 56 and 57 fastened to anchors 58 set in the bottom. Tie lines 56 are secured to the baffle by being tied to lug 59 mounted at the top of inclined member 20, and tie lines 57 are secured to a lower part of the baffle by being fastened to a lug 60 mounted on inclined member 20.

Referring to FIG. 1, it will be seen that the panels 26 are so arranged on the baffle 12 that they open when the motion of the water is in the direction of the shore, and close when the motion of the water is in the direction of the sea.

Referring to FIG. 7, there is shown a schematic, longitudinal cross-sectional view through a long-period wave. The ellipses represent the orbital paths described by individual particles at various depths. The wave energy is distributed throughout the entire water depth. As a result, particles at the bottom describe a linear path where-

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as particles at lesser depths describe elliptical paths. The paths of all particles within any particular vertical cross-section will describe confocal ellipses. During the time required for one complete wave length to pass a given vertical cross-section, e.g., section A—A, any individual particle will have traversed one complete elliptical orbit. Assuming that a baffle is located in the plane A—A and valved to open shoreward as shown by the dotted line, the panels will be wide open (position "O") when the crest passes through plane A—A, and will be completely closed (position "C") when the trough passes plane A—A (one-half wave length later).

Referring to the dredging device shown in FIG. 1, its operation is best understood by a consideration of FIGS. 8–12, which schematically illustrate its dredging action as successive waves pass therethrough and toward the shore. (The anchoring lines are not shown.) FIG. 8 represents the dredging device anchored in position and "at rest" in the water, no waves having been encountered, and the bed 62 of material, e.g., sand, silt, etc. not yet having been subjected to dredging and hence being comparatively flat.

As a wave crest advances shoreward and reaches the dredging device (FIG. 9), the direction of water flow is also shoreward (FIG. 7), so that panels 26 open effortlessly, and water flows through the baffle. As the wave trough then advances to the dredging device (FIG. 10), the direction of water flow is seaward rather than shoreward (FIG. 7), and the panels close. Since the stream of water impinging upon the closed panels cannot pass seawardly through the closed panels, it is deflected downward and beneath the baffle and then passes to the seaward side thereof. The water velocities associated with the wave motion are considerable, so that this deflected stream of water exerts great agitation on particles 64 in the bed 62, and actually lifts these particles and maintains them in suspension above the bed seaward of the baffle (FIG. 9).

As the next successive wave crest advances to the dredging device (FIG. 11) the direction of water flow is again shoreward, so that the panels 26 again swing open. As the water passes through the baffle the water carries with it all of the suspended particles 64, and deposits such particles in a zone 66 which is markedly closer to shore than the zone 68 in which the particles were originally located.

Upon permitting the dredging device to continue to encounter successive waves over a period of time, a remarkable quantity of material can be transported from its original zone 68 and deposited shoreward thereof in a zone 66, to actually build up a deposit of appreciable proportions (FIG. 11).

It will be obvious from FIGS. 8, 10 and 12 that the spacing between the bottom edge 70 of the lowest panel 26 and the surface 72 of the bed 62 will affect the dredging operation. This spacing can be controlled and adjusted as desired by simply adjusting the relative position of the slot 22 with respect to horizontal member 16.

In addition, the relative orientation of the baffle 12 in the water will also affect the dredging efficiency. In certain instances it is desirable that the baffle be disposed substantially vertically, e.g., when commencing the dredging. In other instances, better results are obtained when the baffle is inclined with the bottom thereof nearer the shore (as shown in FIGS. 8–12), e.g., after the dredging is well underway, where the particular geometry of the bed renders such orientation advisable, etc. The appropriate baffle orientation is readily secured and maintained by means of either tie ropes 56 or 57 or both.

From a consideration of FIG. 12 it will be apparent that at some point the distance between the bottom panel edge 70 and the surface 72 of the bed becomes so great that the agitation of particles in the bed by the water stream is relatively small, whereupon the efficiency of the

dredge is minimal. At such time the baffle can either be lowered by recourse to slot 22 or, alternatively, the dredge can be moved seaward an appropriate distance and the whole operation can be then commenced anew. Such seaward positioning is readily obtained by appropriate adjustment of tie ropes 56 and 57.

From the preceding, it will be seen that our invention readily lends itself to the use of a series of our dredging devices appropriately spaced from one another, whereby the most seaward dredge will transport material thereunder to a more shoreward zone, the dredge adjacent to such most seaward dredge will transport material thereunder (and material transported thereto by the most seaward dredge) to a still more shoreward zone, etc.

Referring again to FIGS. 8-12, it will be seen that each panel 26 is slightly curved at the bottom part thereof. (See also FIG. 12.) We have found this construction desirable in that it appears to promote the piling up of the material on the shoreward side of the baffle.

The simpler straight or planar panel (FIG. 14) can, of course, also be used and very satisfactory results are obtained.

Other alternative panel constructions are illustrated in FIGS. 15-18. Where it is desired to dredge a channel or the like, either of "plow" type constructions shown in FIGS. 15 and 16 is particularly suitable. Utilizing such a construction, material in the bed will be pushed to the sides of the panel, thereby effectively dredging a channel.

FIGS. 17 and 18 illustrate two additional embodiments wherein the panel is so designed as to induce additional turbulence in the water stream passing thereunder. Thus, FIG. 17 shows a panel wherein the lower (free) edge has been V-notched, whereas in FIG. 18 the free edge has been provided with a series of helically ridged apertures. In the former instance the V-notches will promote additional swirling and turbulence as the water passes through the notch and beneath the panel. Similarly, in the latter instance the helically ridged apertures will promote actual water vortexes and thereby increase the agitation.

The anchoring loads will depend upon the number of panels used. For example, for a given baffle if the panels extend through the entire water depth the anchoring loads will be appreciable on the shoreward side, since the closed panel area will be considerable. However, if panels are used only at and near the bottom of the baffle as shown in FIG. 1, the anchoring loads are considerably reduced because water flowing seaward will impinge on a much smaller total panel area.

In accordance with yet another embodiment of our invention, we have found that the anchoring loads can be markedly reduced by incorporating one or more baffles shoreward of the one or more dredging baffles, which shoreward baffle(s) is valved seawardly, so as to permit the passage of liquid therethrough in a seaward direction but to prevent passage of liquid therethrough in a shoreward direction. This embodiment is schematically illustrated in FIG. 19.

The seawardly valved shoreward baffle 76 may be constructed in a similar manner as dredging baffle 12, although its depth is not so great since it is not serving as a dredge but merely to reduce the anchoring loads on the shoreward tie ropes 56 and 57 secured to the shoreward baffle. Shoreward baffle 76 is secured to dredge baffle 12 both at or near the water line and at or near the bottom by means of tie lines 78. As is fully explained in our application Serial No. 178,842, filed March 12, 1962, provision of a pair of oppositely valved baffles, in instance baffles 12 and 76, causes a damping or attenuation of waves as they pass therethrough and toward the shore. Shoreward baffle 76 thus cooperates with dredge baffle 12 so as to effect a degree of attenuation, and its presence substantially reduces the mooring loads on the shoreward tie ropes 56 and 57 of shoreward baffle 76.

The following example will further illustrate our invention.

EXAMPLE

A baffle similar to that shown in FIG. 1 was constructed. This baffle contained two panels 26 made of relatively rigid plastic ("Royalite"). Each panel was 16 $\frac{3}{4}$ inches wide, 3 $\frac{5}{16}$ inches deep, and $\frac{1}{16}$ inch thick. The panels were slightly curved at the free edge thereof as shown in FIG. 8. The panels were mounted on stainless steel rods 28 as shown in FIG. 1. Each such rod was connected at the ends thereof to inclined member 20, which member was $\frac{1}{2}$ inch wide. The spacing between members 20 was 16 $\frac{3}{4}$ inches, so that the panels could swing freely. Rods 28 were spaced 2 $\frac{7}{8}$ inches from each other so that each panel pivotally mounted on one such rod would, when vertically inclined, have its lower side abut and rest against the next lower rod 28. A pair of floats 14 were secured to the baffle as shown in FIG. 1. The float was made of "Ensolite" brand extended elastomer. Each float was 18 inches long, 16 $\frac{1}{2}$ inches wide, and 3 inches deep. To the lower edge of each panel was secured a thin ($\frac{1}{10}$ inch) strip of lead, whereby to insure a prompt "snapping" action of the panel.

The wave channel in which our baffle was used consisted of a transparent, steel reinforced basin 30 feet in length, 27 inches deep, and 18 inches wide. A sand layer 3 inches in depth was evenly distributed over the bottom of the channel. The still water depth in the channel was maintained at 16 $\frac{1}{4}$ inches as measured from the bottom of the channel. Waves were generated by a bottom-hinged, flat plate wave generator driven by a pneumatic servo motor. The generator was 17 $\frac{3}{4}$ inches wide and 32 inches deep, so that the top thereof extended above the channel. Wave conditions could be altered by means of a pressure regulator, flow control valves and proximity switches (not shown). Perforated wooden block wave absorbers were located at each end of the channel to minimize wave reflections from the ends of the channel. The baffle was held in substantially vertical position by wires 56 and 57 attached to lugs 59 and 60.

Initially the bottom of the baffle, that is, the free edge of the lowest panel 26, was suspended about 3 and $\frac{1}{2}$ inches above the three-inch layer of sand. The distance from the water line to the bottom edge of the lowest panel was 9 $\frac{3}{4}$ inches. The wave generator was then turned on and waves having a wave length of 9.4 feet and an amplitude, a , of three inches, were propagated. Note that when the first trough comes through, the distance from the free edge 70 of the lowest panel 26 to the bed 72 is one-half inch. As the generated waves pass through the dredging baffle one could visually observe the dredging of sand. That is, particles of sand were picked up by the water stream flowing down the shoreward side of the baffle, beneath it, and seaward thereof. These particles were highly agitated by the water stream and were held in suspension until the crest of the next wave passed through the dredge baffle, whereupon the suspended sand was also transported through the baffle openings and deposited shorewardly of the baffle. During the course of about eight hours time, the horizontal, vertical, and angular orientations of the baffle were varied so as to provide continuous effective dredging. After such time a sand pile 14 $\frac{1}{4}$ inches high and 4 $\frac{1}{2}$ feet long was obtained.

It will be apparent from the foregoing that our dredging device is markedly effective in transporting large quantities of solid material from a given location to another desired location.

Naturally, the size of a dredging device constructed in accordance with our invention may vary, depending upon the area to be dredged, the distance which the dredged material is to be transported, the width and depth of the channel to be dredged, the particular water conditions to be encountered, e.g., wave length, water depth, wave amplitude, etc.

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In one desired application, our dredging device can be disposed relatively close to the shore line, that is, along a relatively shallow zone wherein the bed gradually slopes upwardly toward the shore. The characteristics of shallow-water waves are altered as such waves advance and break upon the sloping bed. Accordingly, when our device is disposed relatively close to the shore, instead of causing bed material to be lifted and deposited to form a mound immediately shoreward of the device, the so-dredged material is actually carried by the breaking wave and is deposited over the sloping beach to thereby build up the beach and compensate for erosion.

Variations can, of course, be made without departing from the spirit of our invention.

Having thus described our invention, what we desire to secure and claim by Letters Patent is:

1. A dredging device for transporting material beneath a liquid surface from one zone to another, said device being actuated by energy associated with waves propagated in said liquid, said device comprising a float means, a horizontal support member attached to each side of said float means, an elongate member movably attached to each of said support members and depending into said liquid to a level beyond said float means, a baffle mounted between the lower ends of said elongated members and spaced from said float means to define an unobstructed passageway therebetween, said baffle having a series of openings disposed at different levels in substantially a common plane with pivotally mounted closure means depending from horizontal pivot means at different levels over each of said openings, each of said closure means being larger than said openings and swingable in the same direction from each level of pivot means to uncover said openings so as to permit liquid to flow therethrough in one direction only, said elongate members being pivotally mounted to said horizontal members to fixedly position the baffle with said plane of the openings at a selected angle relative to the support members and further being movable vertically relative to said horizontal members to shift the closure means vertically with respect to said float means, and said device having inextensible and flexible anchoring lines connected thereto and extended beyond said float means in opposite directions from said plane of the openings and secured to fixed anchors provide in the bed of the liquid for positioning said floats on the liquid.

2. The device of claim 1, wherein a series of said baffles are disposed in spaced apart relation from one another and

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interconnected by inextensible flexible lines for defining, said spacing such that material being transported by one baffle is deposited in a zone sufficiently close to an adjacent baffle to permit said adjacent baffle to transport said material to a zone close to a next adjacent baffle.

3. A method of dredging material from a pre-selected zone in the bed of a body of water in which waves are propagated, said waves being characterized by having a shoreward flow of water as the wave crest passes shorewardly over said zone and a seaward flow of water as the wave trough passes shorewardly over said zone, comprising:

permitting the shoreward flow of water of a first wave crest to pass immediately above and unimpededly over said zone;

deflecting the seaward flow of water of the trough immediately following, said first wave crest rapidly downwardly against said zone and therealong in a path of flow seawardly, thereby to agitate particles of material in said bed and cause said particles to go into suspension in the water immediately seawardly of said zone;

and then permitting the shoreward flow of water associated with the next wave crest to pass immediately above and unimpededly over said zone, thereby to carry said suspended particles shorewardly over said zone and deposit them on the bed shorewardly of said zone.

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