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(54) **Title**: METHOD TO REMOVE ALGAE FROM EUTROPHIC WATER

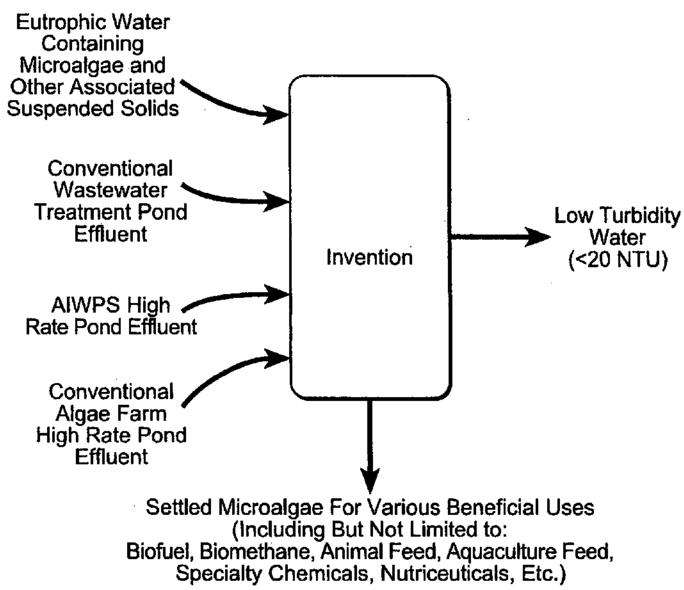

FIG. 1

(57) **Abstract**: The present invention is an improved method for removing microalgae from eutrophic water. The method comprises providing an Algae Settling Pond having an influent transfer means, that comprises a coagulant dosing means; and an effluent transfer means that comprises one or more upflow settlers, one or more floating perimeter baffles, and one or more surface launders. The settlers are fixedly positioned within the Pond and surrounded by the floating perimeter baffles, so that water is directed through said settlers to the surface launders to provide high level transfer for water out of the Pond. Eutrophic water is dosed with a cationic coagulant and then transferred to the Algae Settling Pond. The dosed water is directed into and up along the upflow settlers so that the algae is enable to agglomerate info floes and settle on a surface of the upflow settlers and slide down to the base of the Pond.

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METHOD TO REMOVE ALGAE FROM EUTROPHIC WATER

Field of the Invention

The invention relates to methods of removing microalgae and suspended solids from eutrophic, algae-containing water. More specifically, the invention relates to methods for optimizing coagulation, flocculation and gravity sedimentation removal of microalgae and other suspended solids from eutrophic, algae-containing water.

Background of the Invention

Eutrophic water bodies are defined as any open surface water body, such as a wastewater treatment pond, that contains plant nutrients and therefore a significant concentration of photosynthetic microorganisms, primarily green microalgae. In severely contaminated eutrophic water bodies, so-called hypereutrophic water bodies, blooms of cyanobacteria may out-compete the green microalgae. Once these plant nutrients, from various sources, have been removed from the water column via microalgal assimilation, the algae must themselves be removed from the water column in order to complete the tertiary stage of eutrophic water treatment (wastewater treatment).

Wastewater effluents containing algae often fail to meet their biological oxygen demand (BOD) and total suspended solids (TSS) regulatory permit requirements. Eutrophic water containing algae is normally not suitable for direct potable treatment without first removing the algae. In the past, it has been difficult to remove single-cell species of algae due to their small size and charge repulsion without the use of chemical coagulation followed by dissolved air flotation. Dissolved air flotation is a mechanical means of removing coagulated and flocculated algae by flotation. Dissolved air flotation requires energy and skilled operations. More economical, less mechanically complex, yet equally efficient algae removal methods are needed in eutrophic water treatment. Eutrophic water treatment includes raw water potable pretreatment, wastewater treatment, and the harvesting of commercial algae production ponds also known as High Rate Ponds.

In view of the foregoing, it would be highly desirable to provide an improved and economical method to remove algae from eutrophic water .

References Cited

Downing, J.B., Bracco, E., Green, F.B., Ku, A.Y., Lundquist, T.J., Zubieta, I.X., and W.J. Oswald, "Low cost eutrophic water reclamation using the Advanced Integrated Eutrophic water Pond Systems Technology and reverse osmosis" *Water Science & Technology*, Vol. 45, No. 1, pp. 117-125. 2002.

Green, F.B., "The Energetics of Advanced Integrated Eutrophic water Pond Systems," Doctoral Dissertation, Energy & Resources, University of California, Berkeley, May 1998.

Green, F.B., Lundquist, T.J., Bernstone, L.S. and W.J. Oswald, "Advanced Integrated Eutrophic water Pond Systems for Nitrogen Removal," In: *Water Science & Technology*, Vol. 33, No. 7, pp. 207-217 1996.

Green, F.B., Lundquist, T.J. and W.J. Oswald, "Energetics of Advanced Integrated Eutrophic water Pond Systems" In: *Water Science & Technology*, Vol. 31, No. 12, pp. 9-20, 1995.

Oswald, W.J. and Y. Nurdogan, "Enhanced Nutrient Removal in High-rate Ponds," In: *Water Science & Technology*, Vol. 31, No. 12, pp. 33-43, 1995.

Green, F.B., Bernstone, L., Lundquist, T.J., Muir, J., Tresan, R.B. and W.J. Oswald, "Methane Fermentation, Submerged Gas Collection, and the Fate of

Carbon in Advanced Integrated Eutrophic water Pond Systems" In: *Water Science & Technology*, Vol. 31, No. 12, pp.55-65, 1995.

Oswald, W.J., Green, F.B., and T.J. Lundquist, "Performance of Methane Fermentation Pits in Advanced Integrated Eutrophic water Pond Systems" *Water Science & Technology*, Vol. 30., No. 12, pp. 287-295, 1994.

Oswald, William J., "Advanced Integrated Eutrophic water Pond Systems," In: Supplying Water and Saving the Environment for Six Billion People: Proceedings of the 1989 ASCE Env. Eng. Div. Conf., U.P. Singh and O.J. Helweg, eds., American Society of Civil Engineers, 345 East 47th St., New York, NY 10017-2398, November 1990.

Oswald, William J., "Introduction to Advanced Integrated Eutrophic water Pond Systems,"
Water Science & Technology, Vol. 24, No. 5, pp. 1-7, 1991.

Oswald, William J., "Microalgae and Eutrophic water Treatment," Chapter 12, pp. 305-328. In: Microalgal Biotechnology, Borowitzka and Borowitzka, eds., Cambridge University Press, U.K., 1988.

Oswald, William J., "Large Scale Algal Culture Systems (Engineering Aspects)," Chapter 14, pp. 357-394. In: Microalgal Biotechnology, Borowitzka and Borowitzka, eds., Cambridge University Press, U.K., 1988.

Oswald, William J., "The Role of Microalgae in Liquid Waste Treatment and Reclamation." In: Algae and Human Affairs, C.A. Lembi and J.R. Waaland, eds., Cambridge University Press, 32 E. 57th St., New York, NY 10022, 1988.

Oswald, William J. and Yakup Nurdogan, "An Advanced Dissolved Air Flotation System for Microalgae Separation," University of California, Berkeley, Sanitary Engineering and Environmental Health Research Lab SEEHRL Report No. 87-4, May 1987.

Oswald, William J. and John R. Benemann, "Algal-Bacterial Systems," In: Biochemical and Photosynthetic Aspects of Energy Production, pp. 59-80, Academic Press, Inc., 1980.

Oswald, William J., D.M. Eisenberg, J.R. Benemann, R.P. Goebel, and T.T. Tiburzi, "Methane Fermentation of Microalgae," In: Proceedings of the First International Symposium on Anaerobic Digestion, pp. 123-135, University Colleges, Cardiff, U.K., 1979.

Oswald, William J., "Light Conversion Efficiency in Photosynthetic Oxygenation," Doctoral Dissertation in the Department of Civil Engineering, University of California, Berkeley and Sixth Progress Report, Series 44, Issue No. 6, Sanitary Engineering Research Laboratory SERL 44-6, January 1957.

Brief Description of the Invention

The present invention relates generally to the removal of algae, cyanobacteria and other suspended solids from eutrophic water bodies including but not limited to municipal, industrial and/or agricultural eutrophic water treatment ponds; commercial-scale algae growth ponds; and, eutrophic water bodies in developing countries that are needed for additional drinking water supply but are too polluted to be effectively treated for drinking water. The method of removing microalgae, cyanobacteria, and other suspended solids from eutrophic water bodies is useful in a variety of applications. For instance, if the eutrophic water body or open pond is part of a eutrophic water treatment process and facility, then the removal of total suspended solids (TSS) and the associated biological oxygen demand (BOD) of these suspended solids will be a requirement of the permit of the eutrophic water treatment facility. If the eutrophic water body is a secondary-stage eutrophic water treatment pond, such as the High Rate Pond of an AIWPS eutrophic water treatment facility (Oswald, 1990) whose effluent coming from a high-level transfer contains mostly microalgae and other suspended solids, then the removal of these algal and other suspended solids will complete the secondary and tertiary treatment stages and will reduce the TSS and BOD loading to the downstream water body, for instance a Maturation Pond or a reclaimed water reservoir of an AIWPS Facility. Likewise, if the eutrophic water body is a commercial-scale algae farm or production facility with hundreds of acres of algal High Rate Ponds, then the efficient removal of these suspended growth microalgae will be an essential step in the mass production of microalgae and the targeted specialty chemicals, animal and fish feed, biofuel, biomethane, etc. that are derived from the microalgae.

Eutrophic water bodies may be defined as any surface water body, such as a eutrophic water treatment pond, that is receiving an influx of plant nutrients. From a water quality standpoint, eutrophic water bodies are those that have become contaminated with nutrients and the resulting blooms of photosynthetic microorganisms, primary green microalgae. In more severely contaminated eutrophic water bodies, so-called hypereutrophic water bodies are contaminated with blooms of cyanobacteria. Plant nutrients, such as nitrogen and phosphorus, in the presence of sunlight stimulate the growth of microalgae and cyanobacteria. Once these plant nutrients have been assimilated into microalgae, these microalgae measured as Volatile Suspended Solids must themselves be removed from the water in order to complete the third stage of eutrophic water treatment. Tertiary eutrophic water treatment is defined as the removal of plant nutrients that would otherwise cause eutrophication in a receiving water body into which the treated eutrophic water might be discharged. To complete tertiary treatment in the AIWPS eutrophic water treatment process, it is not sufficient to simply grow microlgae on waste nutrients to provide photosynthetic oxygenation and nutrient removal. Tertiary treatment also requires the removal of algae and other suspended solids, organic and inorganic, to clarify the final effluent or reclaimed water and, by virtue of its clarity (turbidity less than 2 nephelometric turbidity units (NTU)) to enable the use of ultraviolet light for disinfection. In the process of removing the algae in the present invention, other biological and inert suspended solids are also removed. Therefore, this invention refers to a method of removing algae and other suspended solids in order to achieve advanced tertiary eutrophic water treatment by the removal of algae and suspended solids. And the same method may be applied for the removal of algae from commercial-scale High Rate Ponds at algae farms and from eutrophic water bodies in developing countries being tapped for drinking water but for which this novel method of removing algae must precede potable water treatment and disinfection. Otherwise, potable water treatment of eutrophic or highly eutrophic water will be ineffective.

Eutrophic water bodies include but are not limited to High Rate Ponds a type of secondary eutrophic water treatment pond that utilizes microalgae and bacterial. High Rate Ponds were developed by Professor William Joseph Oswald and have are now used in the AIWPS® Eutrophic water Treatment Facilities in the United States and in many countries around the world for municipal, industrial and/or agricultural eutrophic water treatment and, of growing importance today, for large-scale algae farms that are producing microalgae for a variety of commercial products including nutriceutical substances such as betacarotene, animal feeds, biofuels and specialty chemicals. Eutrophic water bodies also include conventional eutrophic water treatment ponds, such as but not limited to those developed by Professor Duncan Mara called waste stabilization ponds. Eutrophic water bodies also include most of the surface water bodies in developing countries due to the lack of sanitation and water pollution control technology, infrastructure and management.

Eutrophic water bodies include municipal, industrial and agricultural eutrophic water whose primary or secondary stage of treatment utilizes, either intentionally or inadvertently, microalgae in the biological treatment process.

Eutrophic water bodies also include algal High Rate Ponds the water in which microalgae is grown commercially, often in large outdoor ponds. These algae farms produce algal biomass for a variety of products including, but not limited to, human nutritional supplements; pharmaceutical products; protein-rich animal feed; immune-beneficial animal feed supplements; aquaculture feed; biofuels such as biodiesel, ethanol or biomethane; and, specialty chemicals. Nutrient-enriched water also includes natural surface water bodies that have become nutrient enriched by natural or cultural (human-caused) eutrophication processes, processes by which nutrients have entered a surface water body such as a lake, reservoir, pond or other surface water body, and have resulted in a bloom of microalgae and other photosynthetic microorganisms. In each case, regardless of the source of the nutrients, the water that is the subject of the present invention contains microalgae and associated suspended solids. In order to improve the quality of the algae-containing water for a subsequent beneficial use, such as irrigation reuse or as a source of raw drinking water after potable water treatment, microalgae and other suspended solids must be removed first prior to the potable water treatment processes. In the case of an algae farm, the microalgae must be first removed or harvested from the nutrient-enriched water media, if the algae biomass is to be processed into a product.

Brief Description of the Drawings

For a better understanding of the invention, reference should be made to the following detailed description taken in conjunction with the accompanying drawings, in which:

FIG. 1 illustrates a simple process schematic of the invention.

FIGS. 2A-2C illustrate process schematics for various configurations of Advanced Integrated Eutrophic water Pond Systems (AIWPS) in which each type of pond may be operated in parallel or in series.

FIG. 3 illustrates the plan view of a typical municipal AIWPS eutrophic water treatment facility.

FIGS. 4A, 4B and 4C illustrate the Algae Settling Pond Influent Transfer Structure and the coagulation dosing station.

FIGS.5A & 5B illustrate a typical Algae Settling Pond, its low level influent structure and its high level effluent transfer structure containing upflow settlers. The Algae Settling Pond is comprised of two volumes: the supernatant volume and the settled algal slurry volume.

FIGS. 6, 7, 7A, 7B & 7C illustrate the Algae Settling Pond effluent structure containing an array of upflow settlers.

FIGS. 8, 8A, 8B, 8C & 8D illustrate the downstream Maturation Pond effluent structures.

Summary of the Invention

The present invention is a simple, effective and economical method to remove microalgae and other suspended solids from eutrophic water. The method of removing algae from eutrophic water includes the step of forming an Algae Settling Pond Influent Transfer Means, an Algae Settling Pond, an Algae Settling Pond Effluent Transfer Means, and finally a Maturation Pond Effluent Transfer Means. The present invention combines unique transfer means and structures, chemical coagulation, flocculation, upflow settlers and gravity sedimentation. The present invention removes microalgae and other suspended solids from eutrophic water using a modest dose of a cationic coagulant. The present invention is more economical and easier to operate than coagulation followed by dissolved air flotation. By removing algae from eutrophic water, the present invention improves the reliability of algae-based wastewater treatment processes, the efficiency of commercial algae production facilities, and the treatability of eutrophic water needed for potable supply.

Description of the Invention and its Preferred Embodiments

It is necessary to remove microalgae used along with bacteria and Archaea in the treatment of municipal, industrial and agricultural eutrophic water. To achieve the treatment objectives and the final effluent quality that is specified in the eutrophic water treatment facility's permit, microalgae and other suspended solids must be removed from the treated eutrophic water. Furthermore, to complete the tertiary stage of eutrophic water treatment, that is, the removal of nutrients, microalgae and the nutrients they have removed from the water column by assimilation must themselves be removed from the water column. Conventional eutrophic water treatment ponds and advanced natural systems such as the shallow, paddlewheel-mixed High Rate Ponds of an AIWPS eutrophic water treatment facility require the removal of algae. In the commercial production of microalgae for products such as biofuels, animal feeds, specialty chemicals, etc., it is also essential to remove the microalgae from their eutrophic growth media in order to harvest and produce the desired algae-based products. And to utilize eutrophic surface water for potable supply purposes, microalgae and suspended solids must be removed from the eutrophic water column prior to potable water treatment.

The present invention is an economical method to remove microalgae and other suspended solids from a variety of eutrophic water types including, but not limited to, secondary waste water effluents such as the effluent from an oxidation pond, a facultative pond, a high rate pond, or similar eutrophic water body.

Figure 1 illustrates a simple process schematic for the invention. Figure 1 provides various types and sources of eutrophic, algae-containing water. The major co-products of the invention are settled microalgae and low turbidity water (clarified tertiary eutrophic water). Figure 1 also provides various options for the settled microalgae including, but not limited to, the production of biofuel, biomethane, fertilizer, animal feed, aquaculture feed, specialty chemicals, nutriceuticals, etc. The other co-product of the invention is low-turbidity (high-clarity) reclaimed water that is suitable for either secondary reclaimed water recycling, further tertiary treatment using multimedia filtration and final disinfection to meet the highest reclaimed water standards in the world, or for subsequent potable water treatment and potable use.

Figures 2A and 2B, illustrate the context of the present invention within process schematics of typical Advanced Integrated Eutrophic water Pond Systems. The present invention begins with the effluent (eutrophic water **26)** of the High Rate Pond. This effluent is discharged from the surface of the High Rate Pond into the Algae Settling Pond Influent Transfer Means. The Algae Settling Pond Influent Transfer Means is comprised of the Influent Transfer Structure **79,** the coagulation station **60,** and the Influent Inlet Pipeline **90.**

The major pond types within an AIWPS eutrophic water treatment facility are: primary Advanced Facultative Ponds **17** including In-Pond Digesters **16,** secondary High Rate Ponds **20,** tertiary Algae Settling Ponds **92,** quaternary Maturation Ponds **100.** Although not shown in these figures, each of these four types of eutrophic water treatment ponds may be operated in parallel or in series.

Depending on the dominant species of microalgae present in the eutrophic water body and the degree of bioflocculation and or autoflocculation that may have taken place in the eutrophic water body, coagulation may be minimized.

Figure 3 illustrates the plan view of a typical municipal AIWPS eutrophic water treatment facility. In Figure 3, the invention is begins with the Algae Settling Pond Influent Transfer Means that conveys eutrophic water from the High Rate Pond **20** to the Algae Settling Pond **92.** The Algae Settling Pond Effluent Transfer Means transfers water from the Algae Settling Ponds **92** to the Maturation Pond **100.** Maturation Pond Effluent is transferred through the Maturation Pond Transfer Means **111** to the next in series Maturation Pond **200.** Final effluent 400 may be recycled or discharged according to local regulations.

As illustrated in Figures 4A and 4B, the Algae Settling Pond Influent Transfer Structure **4A** consists of three chambers: a Forebay **80**, a cylindrical Mixing Chamber **85**, and an Effluent Bay **88**. The high level High Rate Pond effluent (eutrophic water) passes by gravity flow into and down through the Forebay **80** and into a low level transfer **84** at the bottom of the cylindrical Mixing Chamber **85.** The cylindrical Mixing Chamber **85** is mixed by a mechanical Mixer **86.** The coagulated eutrophic water (High Rate Pond effluent) then flows up through the mixing field of the Mixer **86** and overflow the Mixing Chamber **85** by gravity into the Effluent Bay **88.** From the Algae Settling Pond Influent Transfer Structure Effluent Bay **88**, the coagulated High Rate Pond effluent passes out of the transfer structure through the Algae Settling Pond Influent Pipe **90** to a low level outlet beneath the Algae Settling Pond Influent Pipe Canopy **91** (see Fig 5A and Fig 5B) that is located at the deep end of the Algae Settling Pond, just above the Algal Slurry Sump Pump **103** as shown in Figure 5B.

If the dominant species of microalgae are single-cell species, or if the bioflocculation and/or autoflocculation occurring the High Rate Pond or other type of eutrophic water body is insufficient to achieve the desired removal of algae via gravity sedimentation in the Algae Settling Pond and by upflow settlers located in the Algae Settling Pond Effluent Transfer Structure, then a high molecular weight, high charge density, cationic coagulant is dosed into the Forebay **80** of the Algae Settling Pond Influent Transfer Structure **79** from the Coagulation Station **60**. The coagulant is dosed and is dispersed into the entering eutrophic water (High Rate Pond effluent) as it enters the Forebay **80** of the Algae Settling Pond Influent Transfer Structure **79**.

Figure 4C illustrates the Coagulation Station from which the cationic coagulant is supplied. The Coagulation Station **60** (Fig. 4C) consists of a Coagulant Storage Tank **81,** a Coagulant Dosing Pump **82,** a calibration column, and a Coagulant Feed Pipeline **83**. The cationic coagulant is also mixed with the eutrophic water (High Rate Pond effluent) entering the Mixing Chamber **85**. The cationic coagulant causes the microalgae to flocculate, and these larger algal flocs then settle by gravity in the Algae Settling Pond illustrated in Figures 5A and 5B. Removal of microalgae by gravity sedimentation is therefore significantly improved by the combination of chemical coagulation, flocculation and upflow settlers. Static upflow settlers **94** are located in the mid-depth of the high level Algae Settling Pond Effluent Transfer Structure **99** and also in all subsequent downstream transfer structures as may be necessary to achieve the final effluent quality permit requirements. One skilled in the art will understand that to automate the coagulation dosing means an in-line turbidimeter should be installed to relay measured turbidity of the Algae Settling Pond effluent, or other downstream effluent, to the coagulant dosing pump to increase or decrease the chemical dose.

Figures 5A and 5B depict a plan and elevation view of a typical Algae Settling Pond **92**. The Algae Settling Pond Inlet Structure consists of the Algae Settling Pond Influent Pipeline **90** and the Algae Settling Pond Influent Pipeline Canopy **91**. The canopy **91** prevents warmer influent water from rising directly to the surface of the Algae Settling Pond. The floor of an Algae Settling Pond is sloped to a sump from which settled algae is pumped though the Algal Slurry Pipeline **101** to the Headworks **12** in one embodiment of the invention.

The Algae Settling Pond Effluent Transfer Means includes an Algae Settling Pond Effluent Structure **99** (shown in Figs 7A, 7B, 7C) that is located in the shallow end of the Algae Settling Pond **92.** This configuration maximizes the potential for gravity sedimentation of the coagulated and flocculated algae because the eutrophic water must pass from one end of the pond to the opposite end and from the low level inlet to a surface outlet. The coagulated and flocculated algae settle into an Algal Slurry **102** on the sloped floor of the Algae Settling Pond **92.**

In one preferred embodiment of this invention, the settled algae are harvested by decanting the Algae Settling Pond Supernatant **105** through the Decant Pipeline **106** to the surface of the Advanced Facultative Ponds. After the supernatant has been decanted, then the Algal Slurry **102** is pumped through the Algal Slurry Pipeline **104** by an Algal Slurry Sump Pump **103** to the Headworks **12**.

Figures 6, 7A, 7B, and 7C illustrate the Algae Settling Pond Effluent Transfer Means comprising the Algae Settling Pond Effluent Transfer Structure **99**, the upflow settlers **94**, the floating perimeter baffle **95**, the surface launder **96**, and the effluent pipeline **98**. Effluent from the Algae Settling Pond is discharged through the high level Algae Settling Pond Effluent Transfer Structure **99**. Floating Perimeter Baffles **95** extend from Floatation Booms **97** down to the base of the upflow settlers. These Floating Perimeter Baffles direct the effluent **93** flow upwards through the settlers to the water surface. This water surface is subscribed by the floating perimeter baffles and into one or more surface launders **96** through crown weirs before being discharged through the Algae Settling Pond Effluent Pipeline **98** to the Maturation Pond **100**. The upflow settlers **94** enhance sedimentation by reducing the settling distance from several feet to a few inches and by providing a surface on which algal flocs can accumulate before sliding down and out the upflow settlers to the Algae Settling Pond floor into the Algal Slurry **102**.

The Algae Settling Pond effluent is discharged into the first Maturation Pond **100** through a mid-depth inlet pipe. The water passes through the first Maturation Pond **100** and enters the first Maturation Pond Effluent Transfer Means, including the Maturation Pond Effluent Transfer Structure **111** that is adjacent to the floating vertical baffle **119** that divides Maturation Pond 1 **100** from Maturation Pond 2 **200** (see Fig 3).

Figure 8 illustrates a plan view of the Maturation Pond Effluent Transfer, upflow settlers **114**, and floating baffles **116** and **119**. Figures 8A, 8B, 8C, and 8D illustrate the Maturation Pond Effluent Transfer Structure **111** in elevation and perspective. As with the Algae Settling Pond Effluent Transfer Means, the effluent of Maturation Pond 1 enters the transfer structure from below the upflow settlers and flows up and out the high level Maturation Pond Effluent Transfer Structure Outlet **118**. Floating Perimeter Baffles **115** (Figs 8A and 8B) extending from Floatation Booms **116** that surround the Maturation Pond Effluent Transfer Structure **111**. These Floating Perimeter

Baffles **115** are designed to focus the water entering the Maturation Pond Effluent Transfer Structure **111** such that it must pass through the upflow settlers **114,** then through the Maturation Pond Effluent Structure Outlet **118** before being discharged into Maturation Pond 2 **200 (Fig 3).** In like manner, the effluent from Maturation Pond 2 must pass through upflow settlers **114** in the Maturation Pond 2 Effluent Means before passing into Maturation Pond 3 **300** and the final effluent transfer structure.

In one preferred embodiment of the invention, greater than 90% microalgae removal was achieved in the Algae Settling Pond using an average coagulant dose of 54 ppm. After the algae depleted water passes through subsequent Maturation Ponds (including the Maturation Pond Effluent Transfer Means), additional microalgae removal was achieved. It should be noted that the present invention is especially effective for removing single-cell microalgal species that proliferate in conventional facultative ponds, oxidation ponds and waste stabilization ponds. Single-cell microalgal species are less likely to bioflocculate, therefore chemical coagulation is necessary for their effective removal. But when the dominant species of microalgae are colonial, multi-cellular, species, the dose of the coagulant may be reduced significantly. For bioflocculated colonial microalgal species, the upflow settlers will enhance their gravity sedimentation.

The present invention accomplishes what previously could only be accomplished by chemical coagulation followed by dissolved air flotation. With this invention, removing algae with dissolved air flotation has now become an unnecessary expense. The present invention is an efficient and economical method of removing microalgae and other suspended solids from eutrophic water, and its use will reduce the cost of eutrophic water treatment, the production of reclaimed water and the potable pretreatment of eutrophic water. The present invention reduces operational requirements and costs. In one embodiment of the present invention, algal slurry is pumped from the Algae Settling Pond sump through an algal slurry pipeline to the Headworks and thus to the primary anaerobic treatment process. This option eliminates the need for algae drying and handling, while increasing the production and recovery of methane-rich biogas or biomethane (see Fig 1). By returning the settled algae to the primary anaerobic treatment process, primary and secondary biosolids handling and disposal may be avoided for many decades.

The present invention also serves conventional eutrophic water ponds and commercial algae farms producing algae for a variety of commercial products. The present invention also provides an economical method for removing algae from eutrophic surface water bodies whose fresh water supplies are needed for potable supply. By removing the microalgae, cyanobacteria and other suspended solids from eutrophic water bodies, the clarified water may then be subjected more effectively and safely to potable water treatment.

While the present invention has been described with reference to a specific embodiment, the description is illustrative of the invention and is not to be construed as limiting the invention or its various applications. Various modifications may occur to those skilled in the art without departing from the spirit and scope of the invention: a novel method for removing algae and other suspended solids from eutrophic water bodies.

Claims

I claim:

1. A method for removing algae from eutrophic water, the method comprising:

providing an Algae Settling Pond, said Pond having a water influent transfer means and a water effluent transfer means, said influent transfer further comprising a coagulant dosing means, wherein said influent transfer means is configured to channel water from a source through said coagulant dosing means and subsequently into the Pond, said effluent transfer means comprising one or more upflow settlers, one or more floating perimeter baffles and one or more surface launders, wherein said settlers are fixedly positioned within the Pond and surrounded by said floating perimeter baffles, said baffles being configured to direct eutrophic water from the Pond up and through said settlers to the surface launders, said surface launders configured to provide high level transfer for water out of the Pond,

dosing said eutrophic water within said dosing means with a defined concentration of cationic coagulant,

transferring said algae-containing coagulant-dosed water to said Algae Settling Pond,

directing said coagulant-dosed water from the Pond under said baffles and then into and up along said upflow settlers wherein said algae is enabled to agglomerate into flocs and settle on a surface of said upflow settlers and slide down to the base of the Pond, and

directing said algae depleted eutrophic water into said surface launders and out of the Pond.

2. The Method of Claim 1, wherein said eutrophic water further comprises associated suspended solids.

3. The Method of Claim 1, wherein said eutrophic water is alternately selected from the group consisting of eutrophic surface water and algae production facility.

4. The method of Claim 1, wherein said Settling Pond further comprises an internal sump.

5. The method of Claim 1, wherein said upflow settlers may alternately be static plate settlers.

6. The method of Claim 1, wherein said upflow settlers are constructed from material selected from the group consisting of metal, plastic, fiberglass, wood or a combination thereof.

7. The method of Claim 1, wherein the cationic coagulant is dosed into said eutrophic water within a mixing box positioned within the influent transfer means.

8. The method of Claim 7, wherein said cationic coagulant is dosed into said eutrophic water at a concentration between 0 and 150 parts per million.

9. The method of Claim 7, wherein said cationic coagulant is dosed into said eutrophic water at a concentration between 1 and 100 parts per million.

10. The method of Claim 7, wherein said mixing box is located outside said algae settling pond.

11. The method of Claim 7, wherein said mixing box is located within said algae settling pond.

12. The method of Claim 1, wherein said algae depleted euthophic water is directed into said upflow settlers at an upflow velocity of between 1.5 gpm/ft^2 and 3.5 gpm/ft^2.

13. The method of Claim 1, wherein the dosing of said euthrophic water is regulated with data supplied by an on-line turbidimeter.

14. The method of Claim 1, wherein said static plate settler enables the agglomeration and settling of algae to the bottom of the Pond by means of gravity sedimentation.

15. The method of Claim 1, wherein said Algae Settling Pond is used in series with additional Algae Settling Ponds of the present invention.

16. The method of Claim 1, wherein said algae settling pond is used in parallel with additional algae settling ponds of the present invention.

17. The method of Claim 1, further comprising a transfer means that facilitates the movement of settled algae from the bottom of said algae settling pond to a second location where algae can be processed.

18. A method for removing algae from eutrophic water, the method comprising:

providing an Algae Settling Pond, said Pond having a water influent transfer means and a water effluent transfer means, said effluent transfer means comprising one or more upflow settlers, one or more floating perimeter baffles and one or more surface launders, wherein said settlers are fixedly positioned within the Pond and surrounded by said floating perimeter baffles, said baffles being configured to direct eutrophic water from the Pond up and through said settlers to the surface launders, said surface launders configured to provide high level transfer for water out of the Pond,

transferring said algae-containing coagulant-dosed water to said Algae Settling Pond,

directing said coagulant-dosed water from the Pond under said baffles and then into and up along said upflow settlers wherein said algae is enabled to agglomerate into flocs and settle on a surface of said upflow settlers and slide down to the base of the Pond, and

directing said algae depleted eutrophic water into said surface launders and out of the Pond.

19. The method of Claim 18, wherein said algae depleted eutrophic water is directed to one or more Maturation Ponds having effluent transfer means containing upflow settlers in order to further reduce the remaining algae content.

20. The method of Claim 18, wherein said algae depleted water is directed to downstream multimedia filtration and disinfection to meet highest reclaimed water standards.

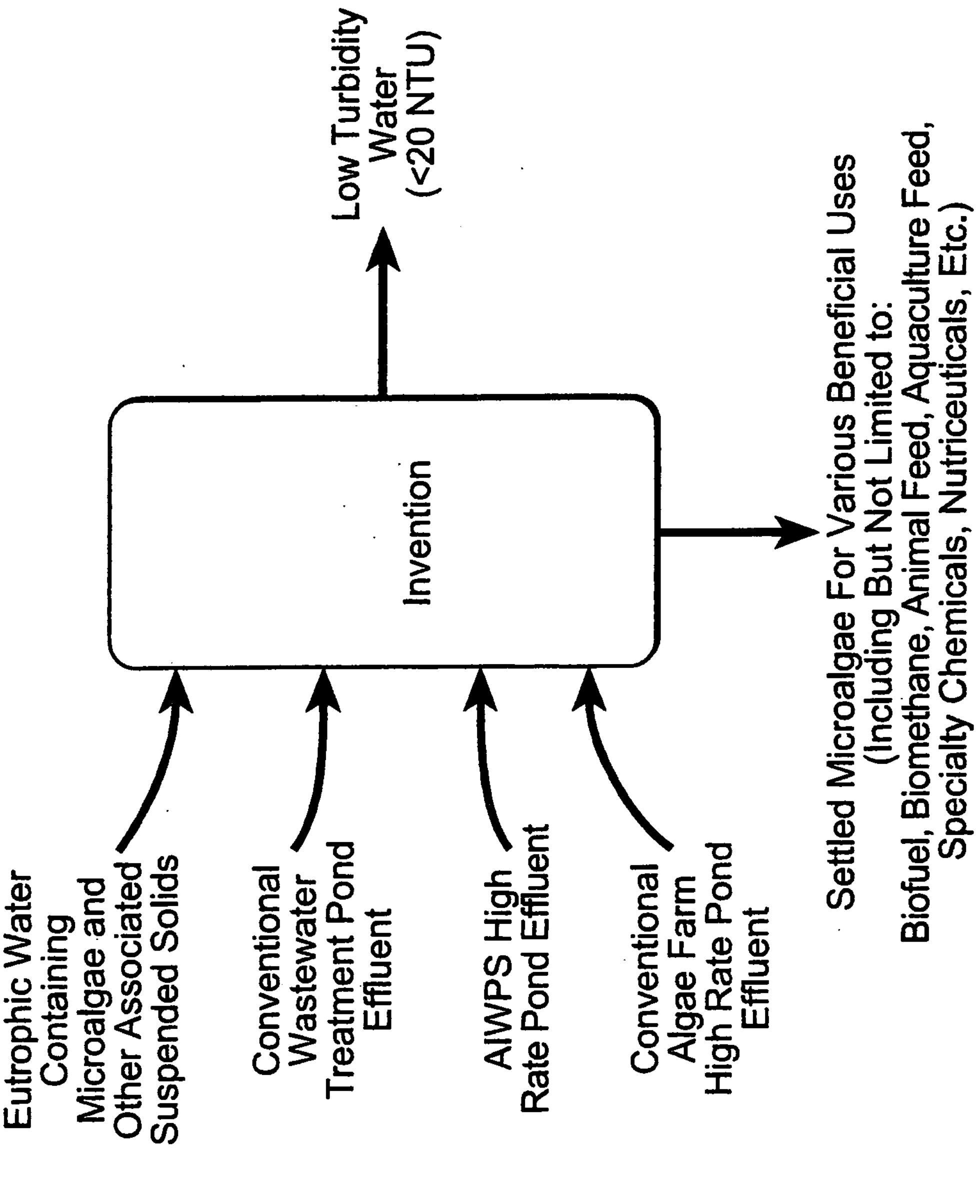
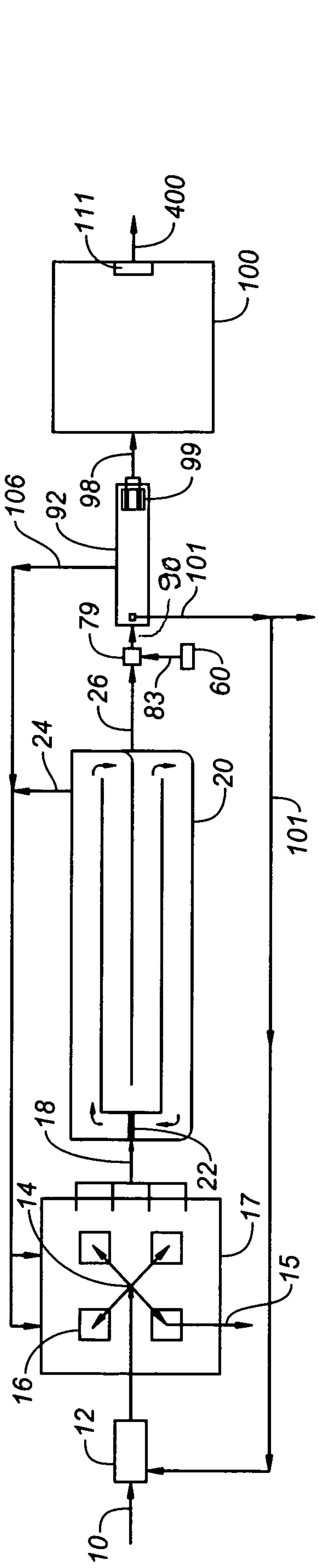

Eutrophic Water Containing Microalgae and Other Associated Suspended Solids
Conventional Wastewater Treatment Pond Effluent
AIWPS High Rate Pond Effluent
Conventional Algae Farm High Rate Pond Effluent
Invention
Low Turbidity Water (<20 NTU)
Settled Microalgae For Various Beneficial Uses (Including But Not Limited to: Biofuel, Biomethane, Animal Feed, Aquaculture Feed, Specialty Chemicals, Nutriceuticals, Etc.)

FIG. 1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98
99
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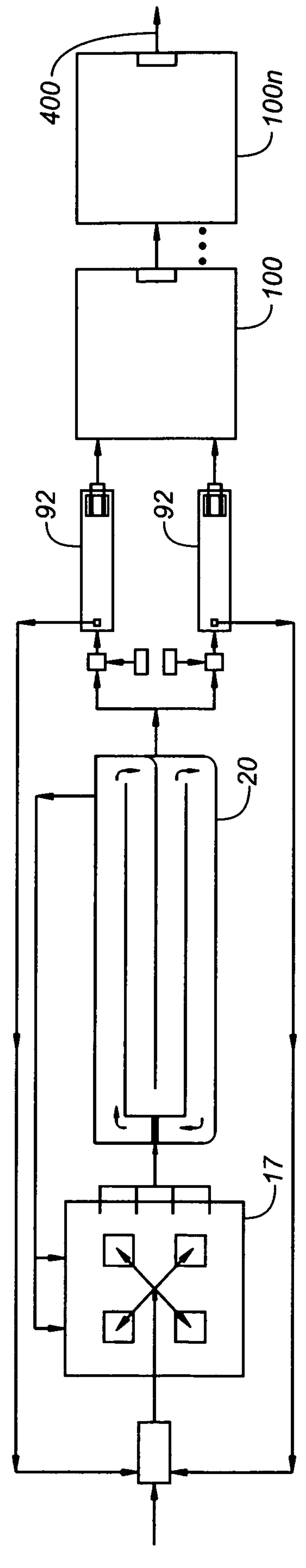
12
10

FIG. 2A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17

FIG. 2B

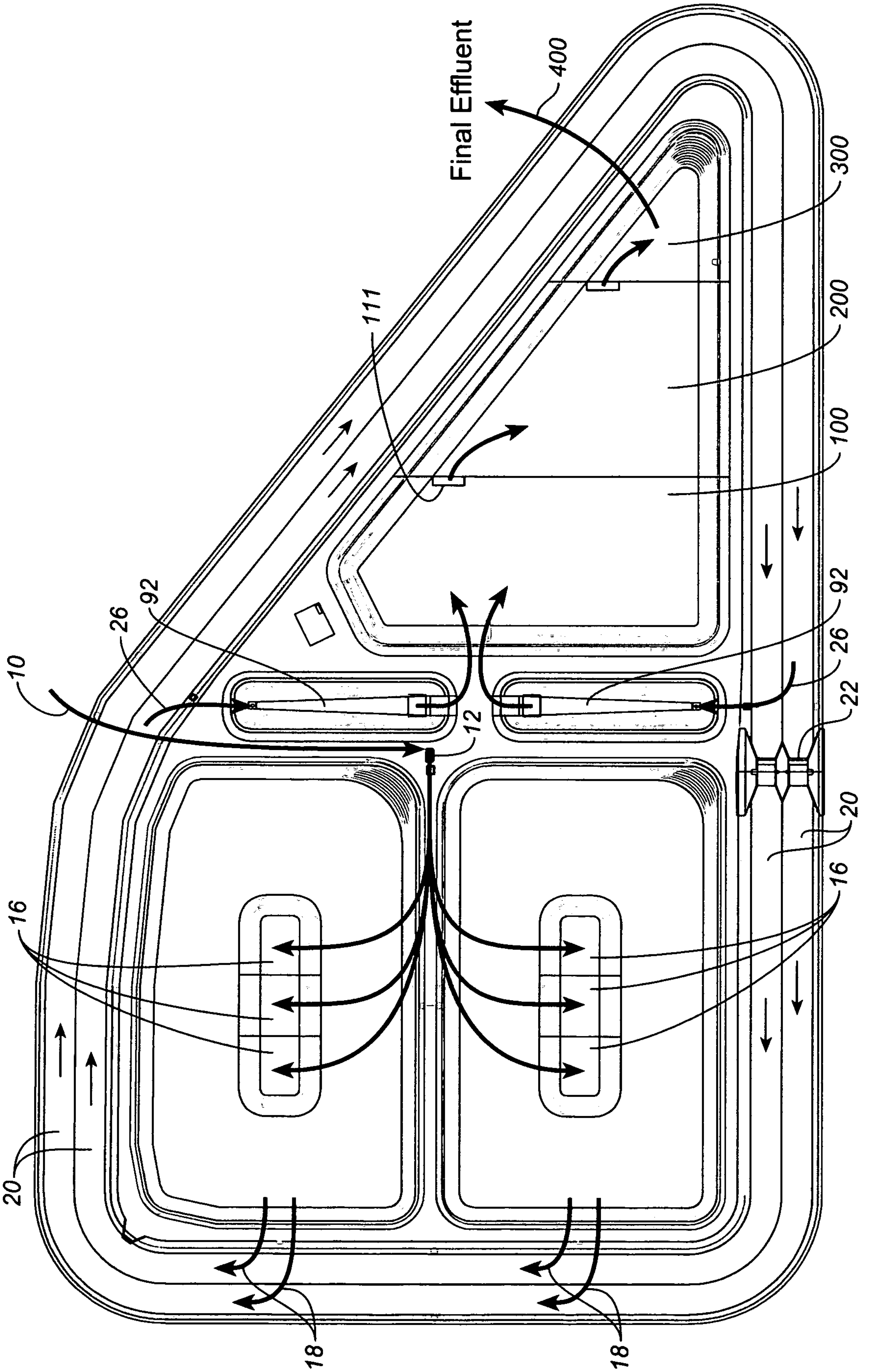

FIG. 3

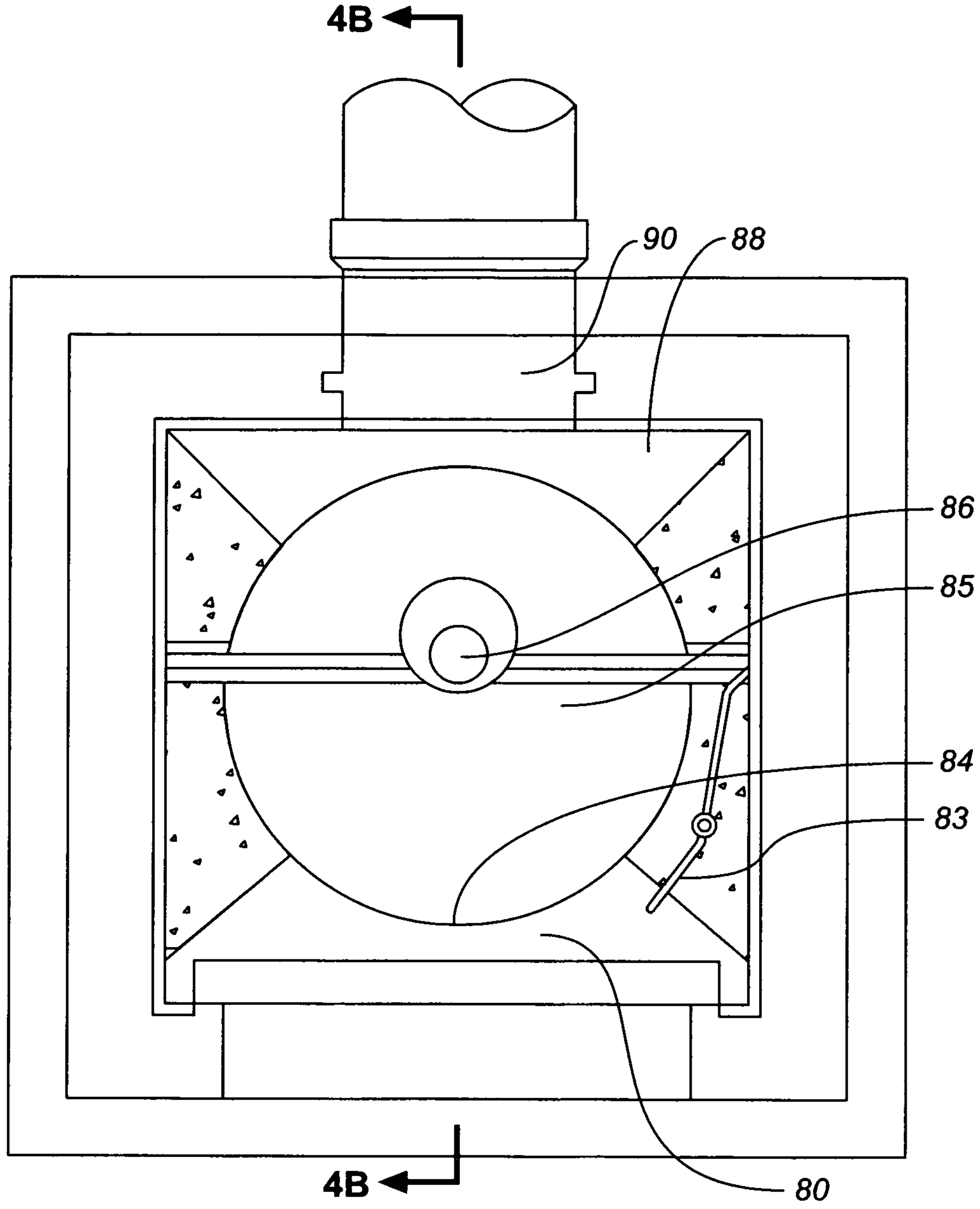

FIG. 4A

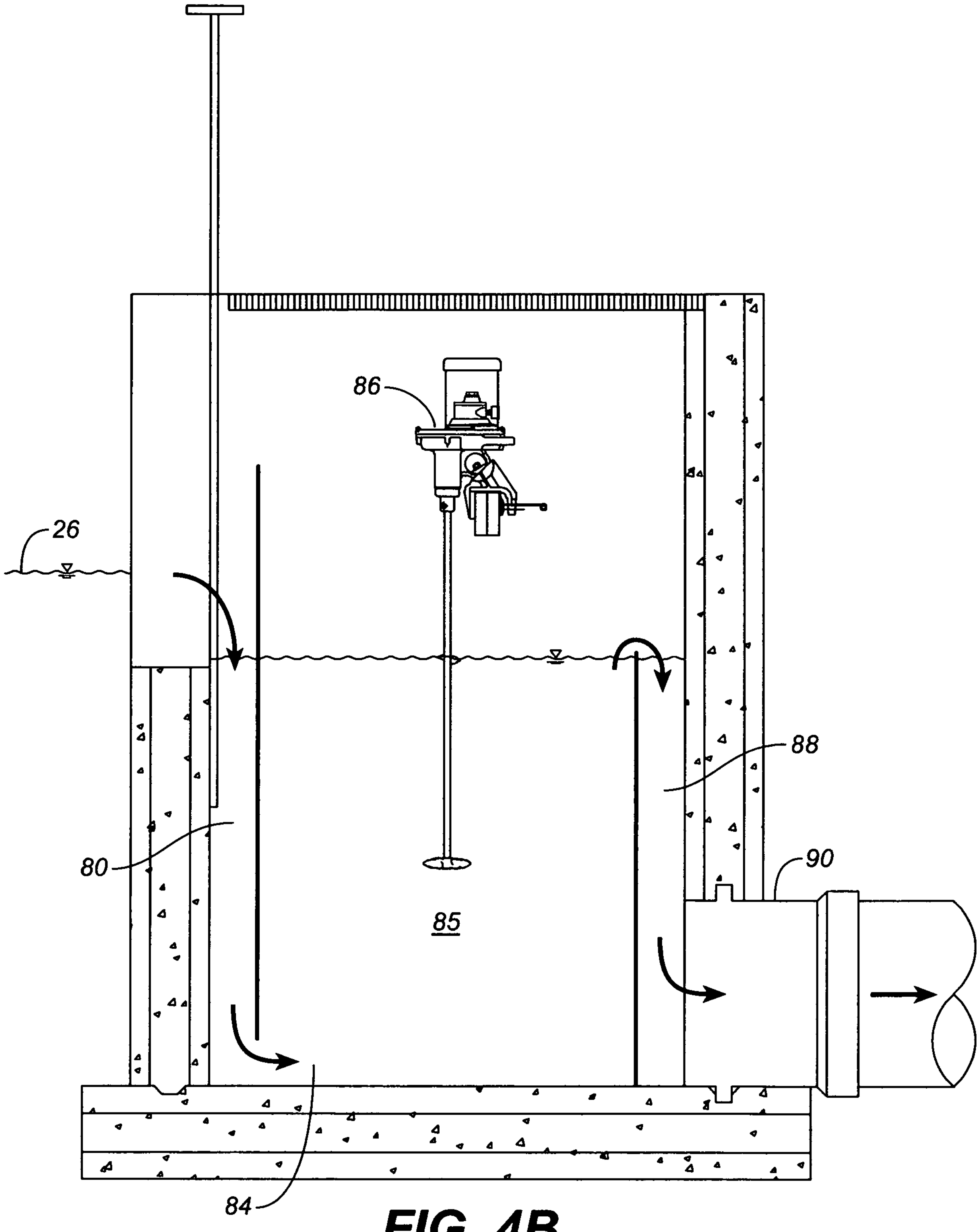

FIG. 4B

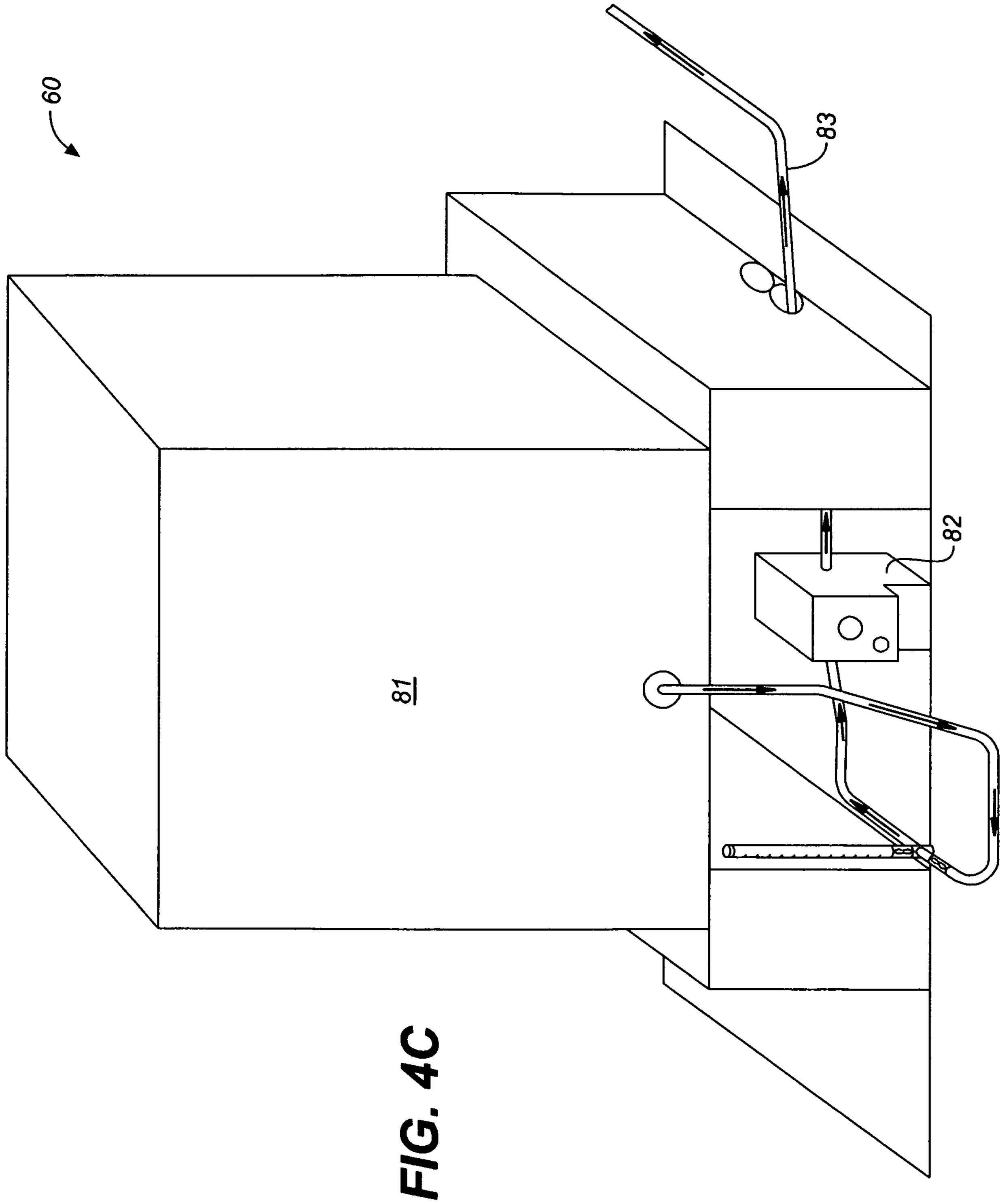

FIG. 4C

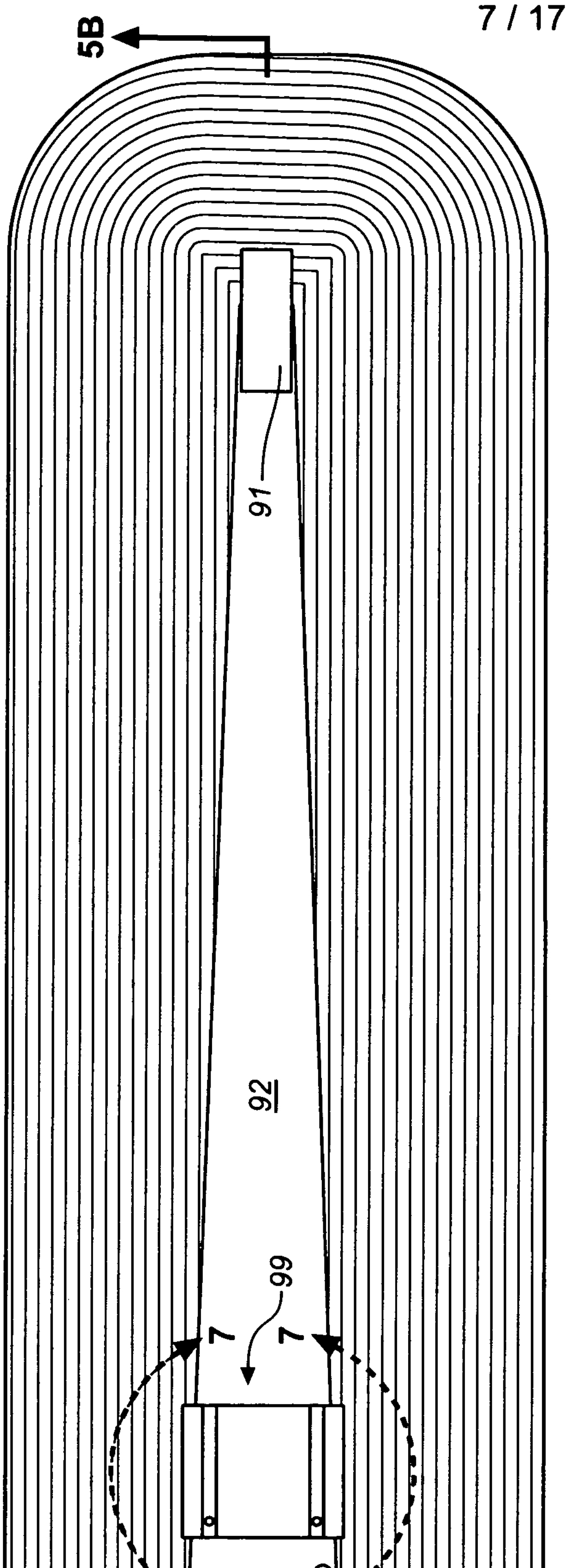

FIG. 5A

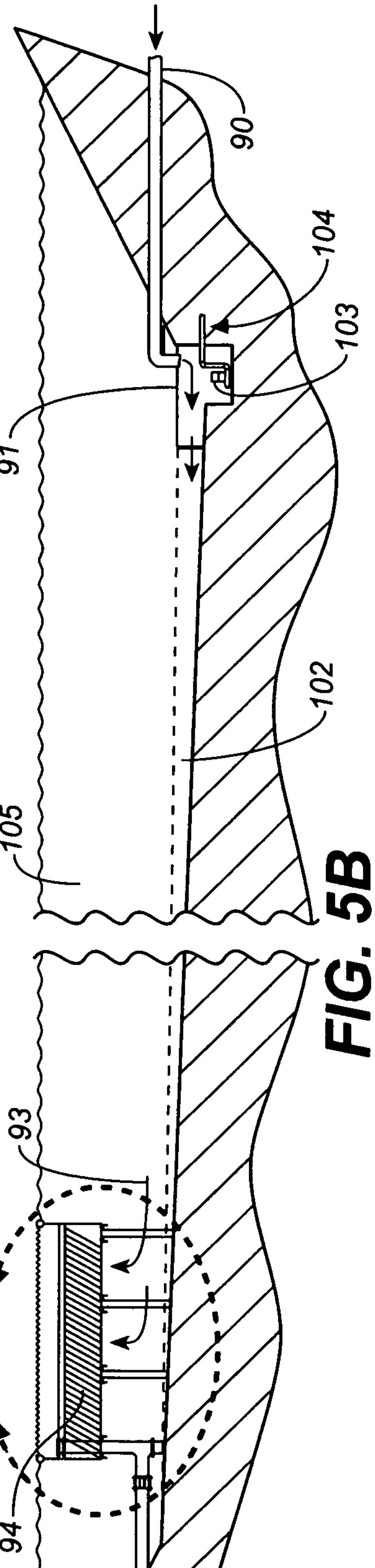

FIG. 5B

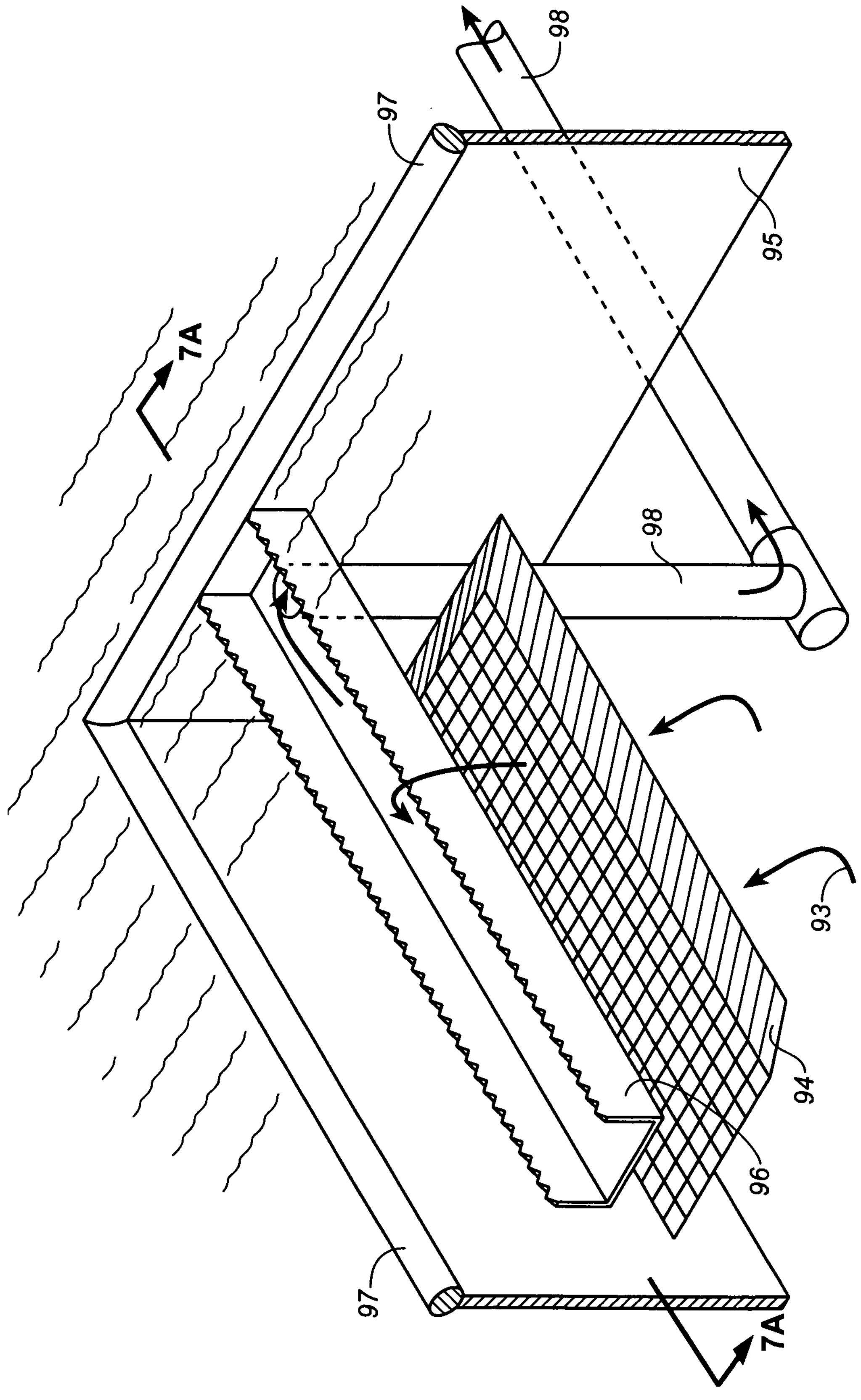

FIG. 6

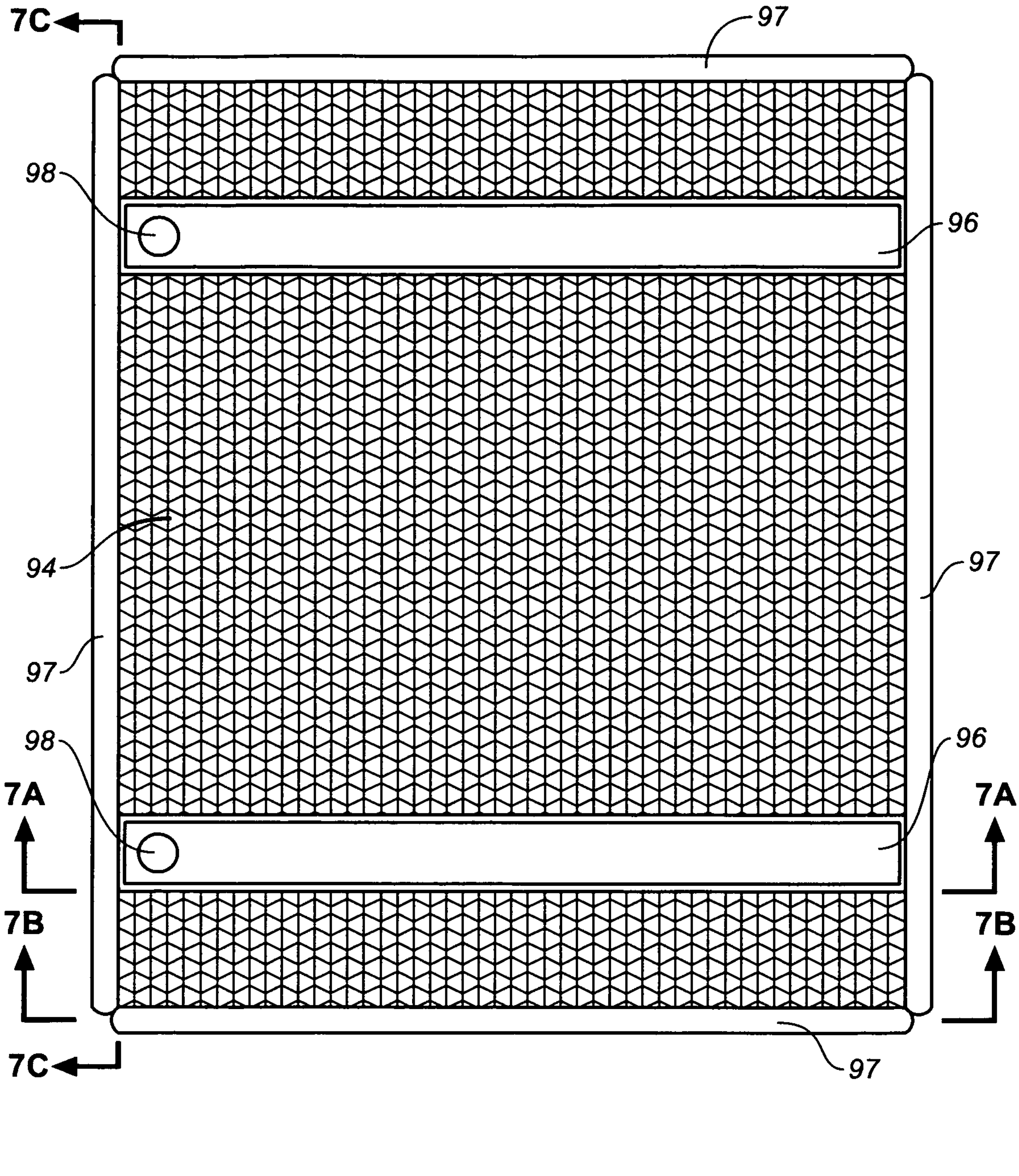

FIG. 7

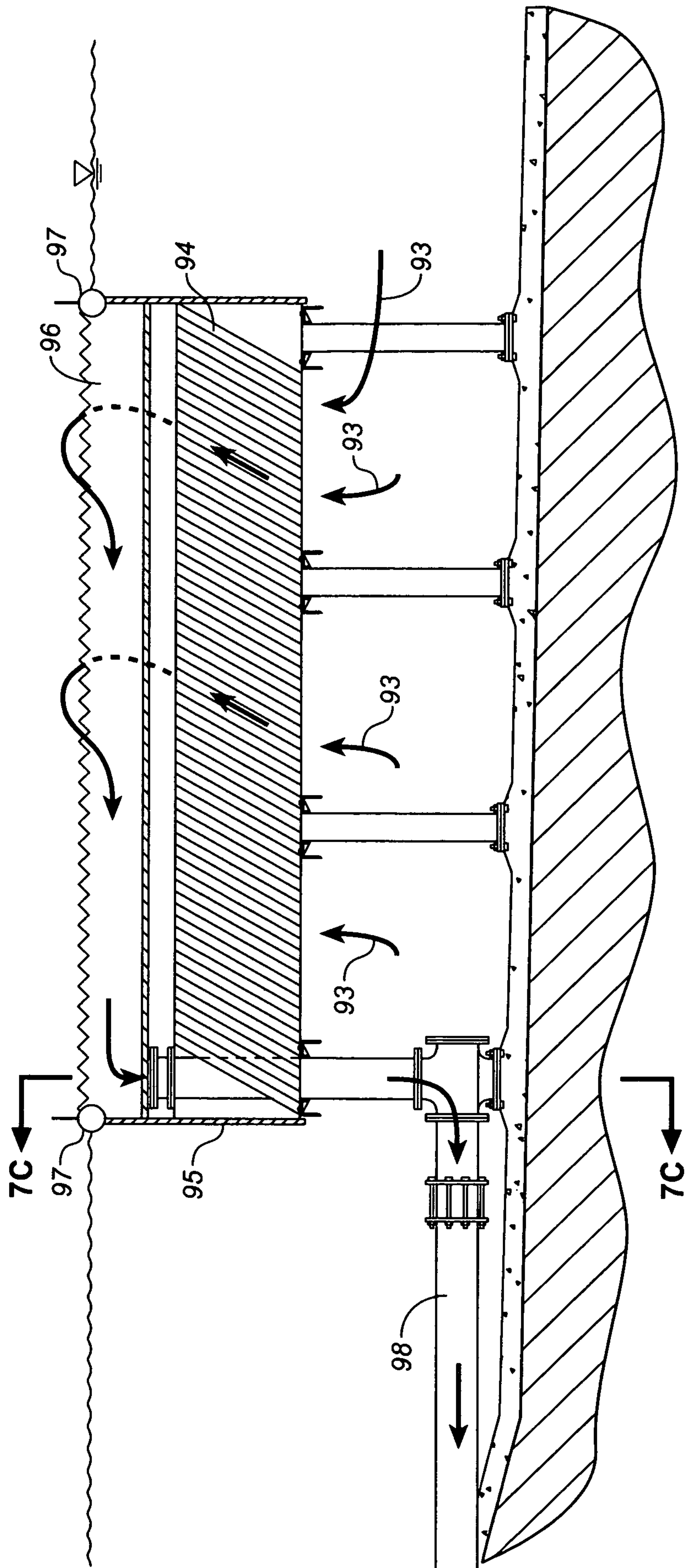

FIG. 7A

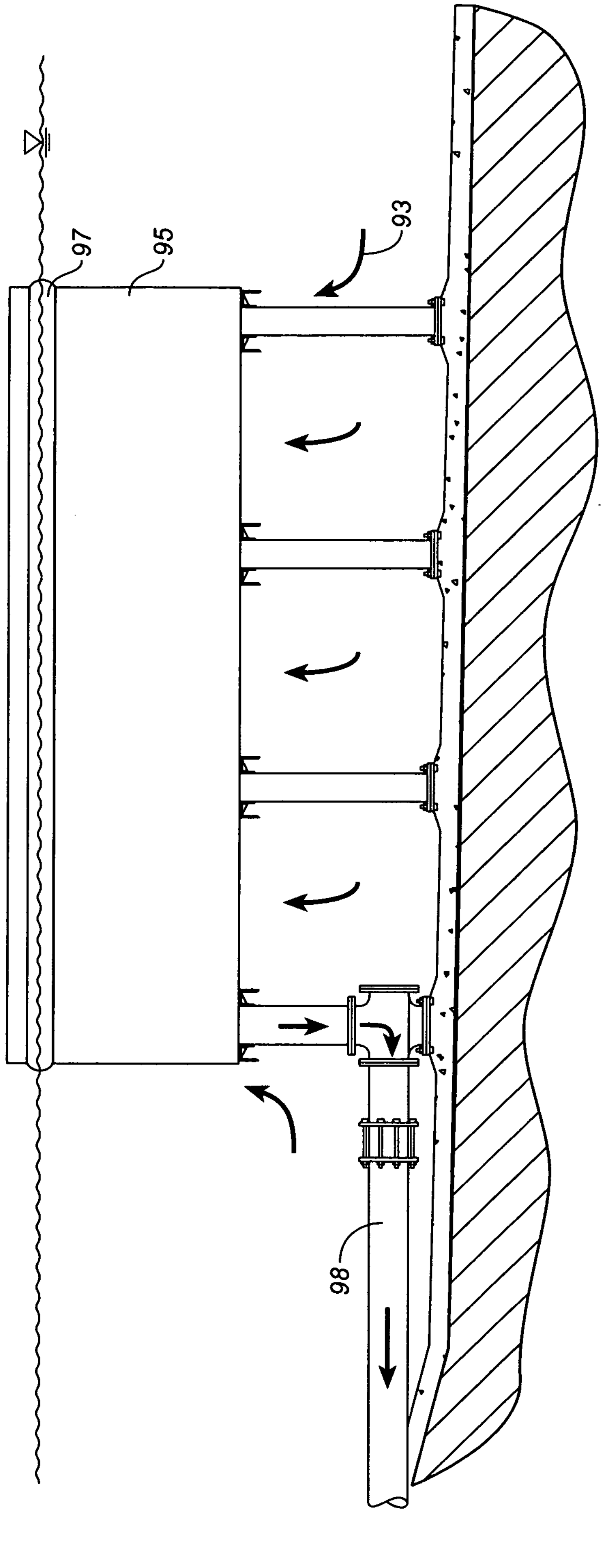

FIG. 7B

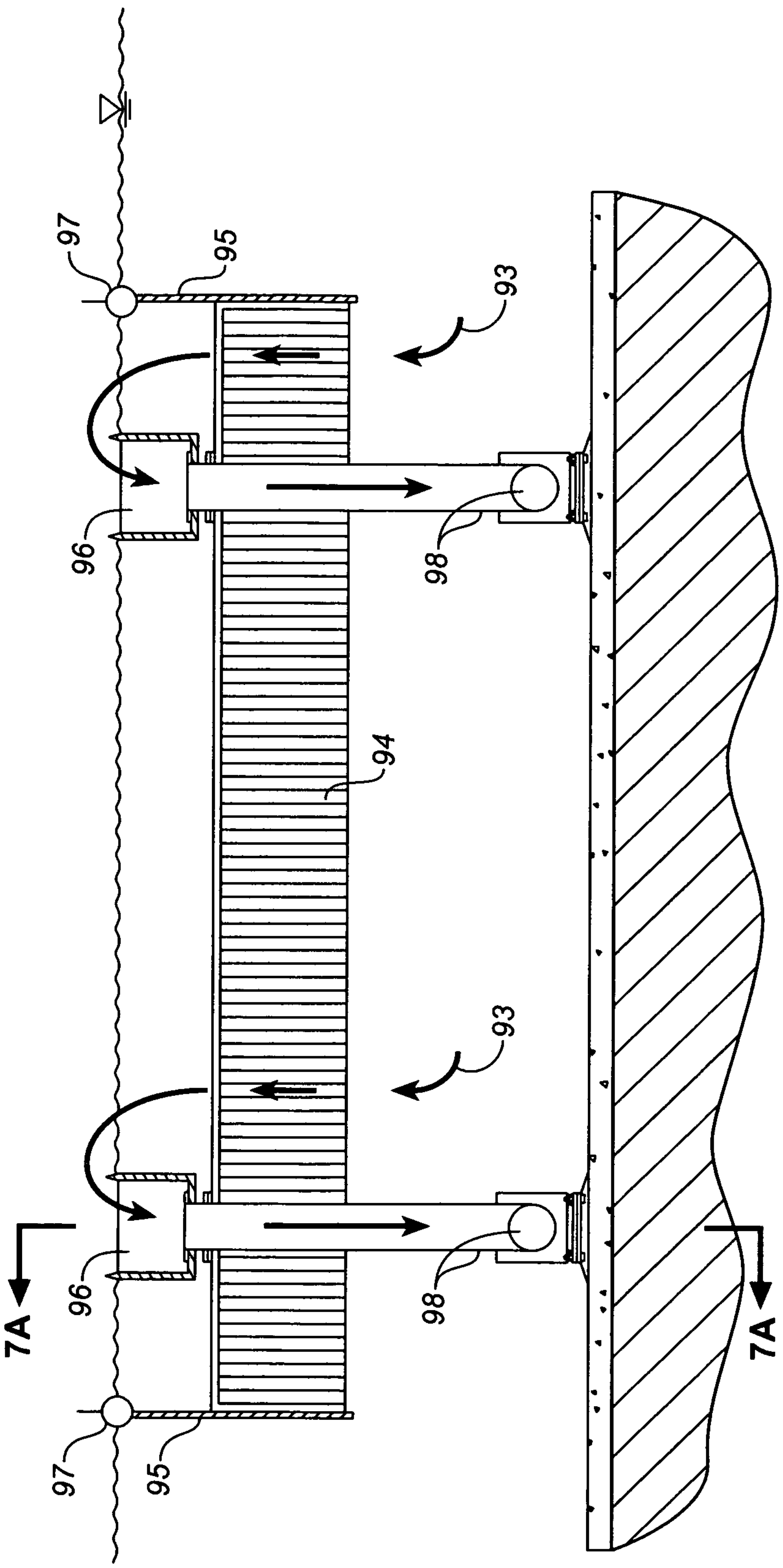

FIG. 7C

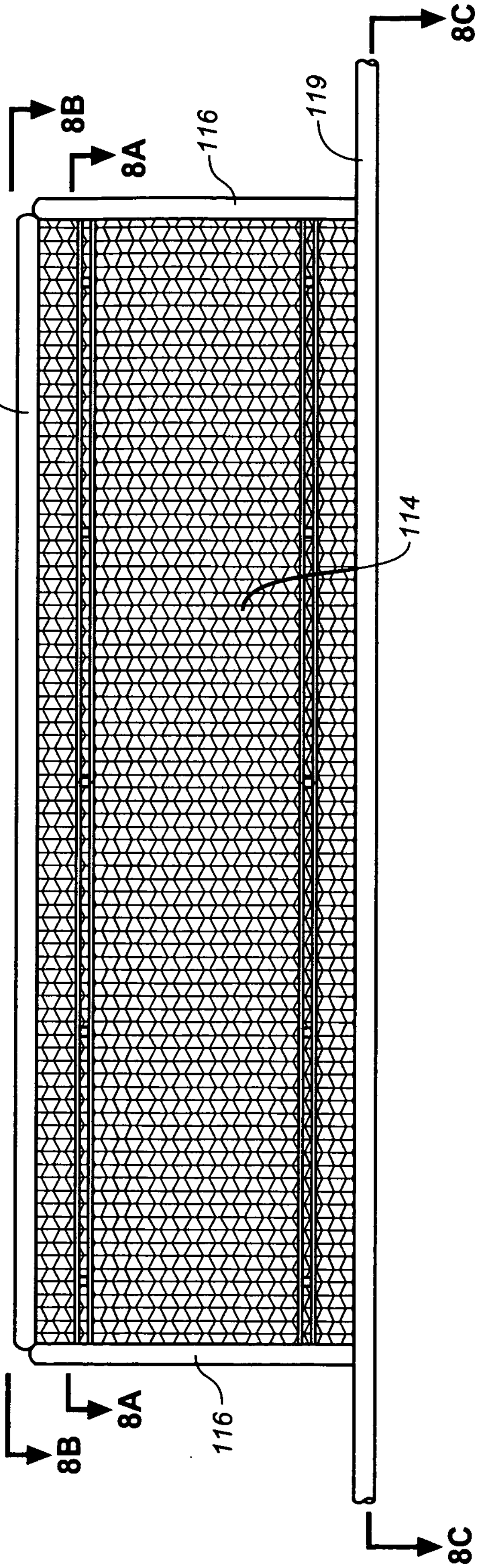

FIG. 8

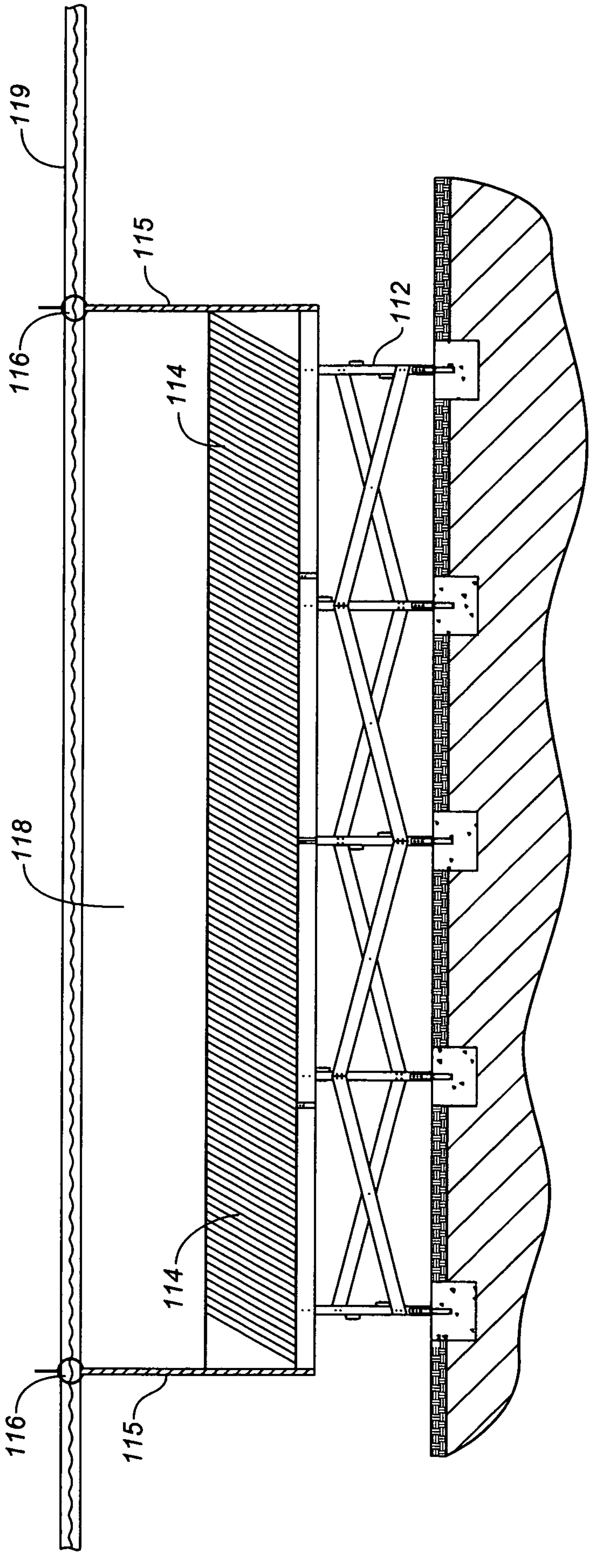

FIG. 8A

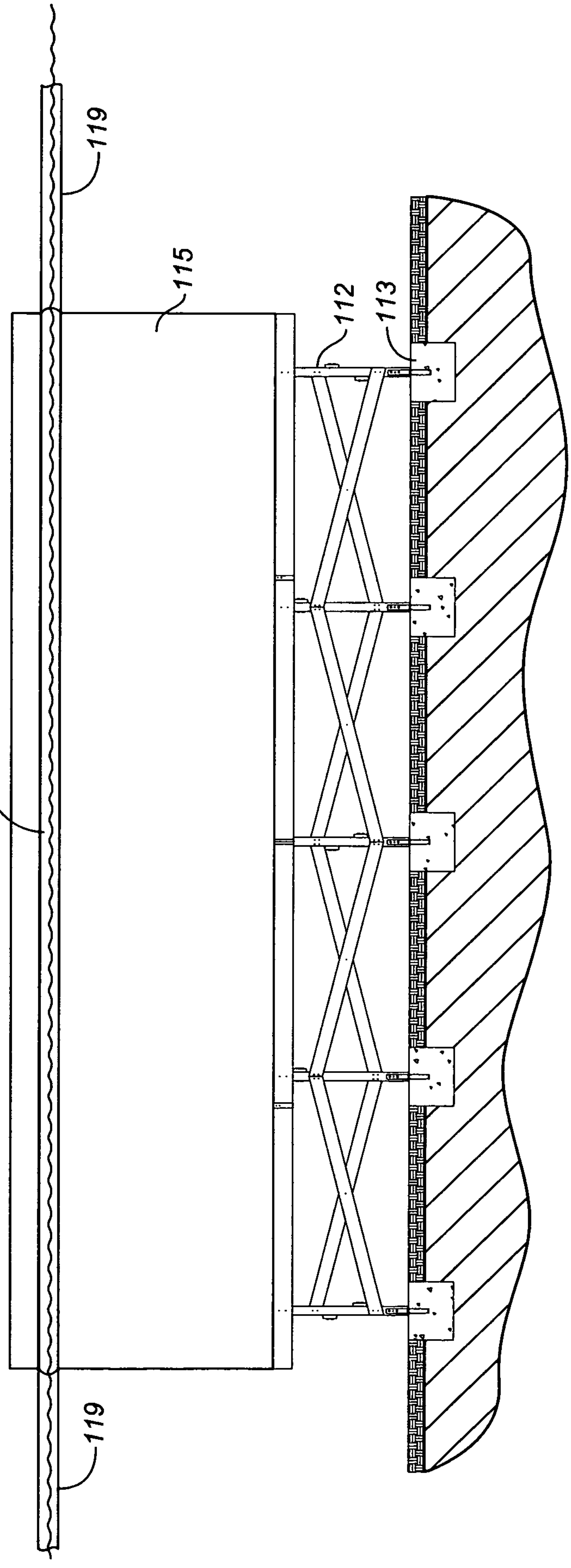

FIG. 8B

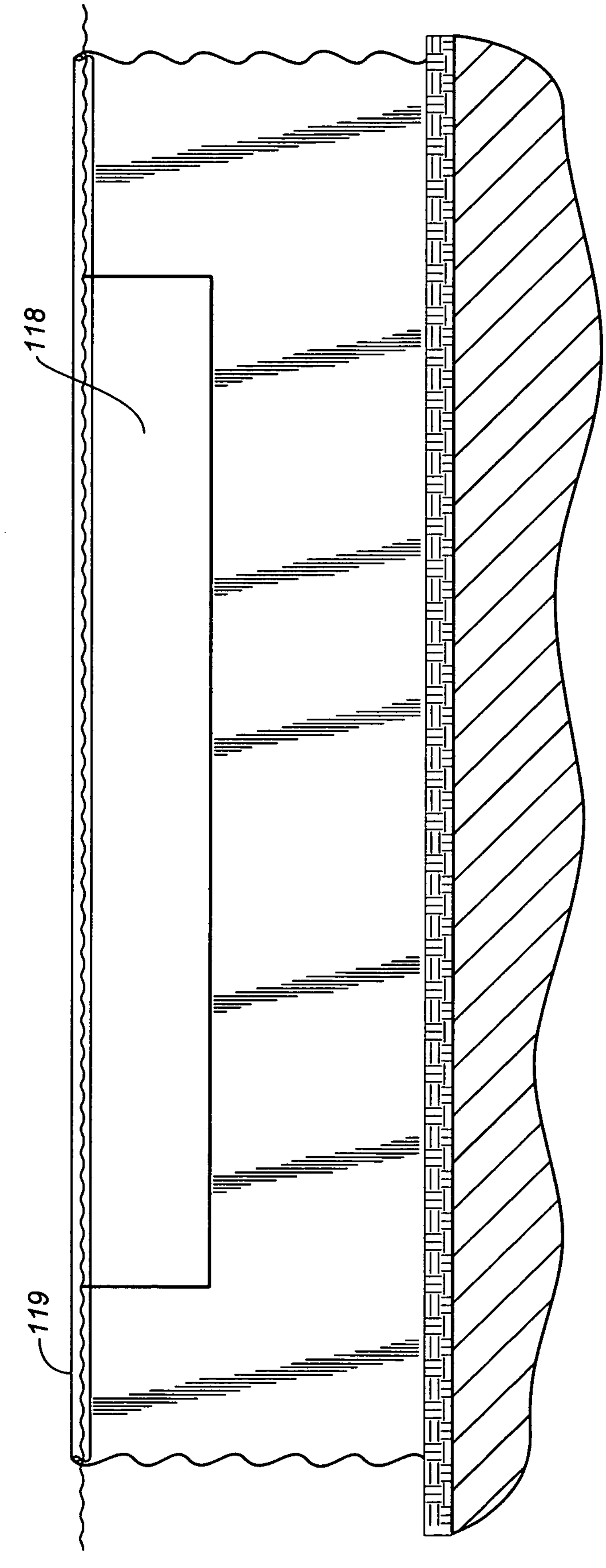

FIG. 8C

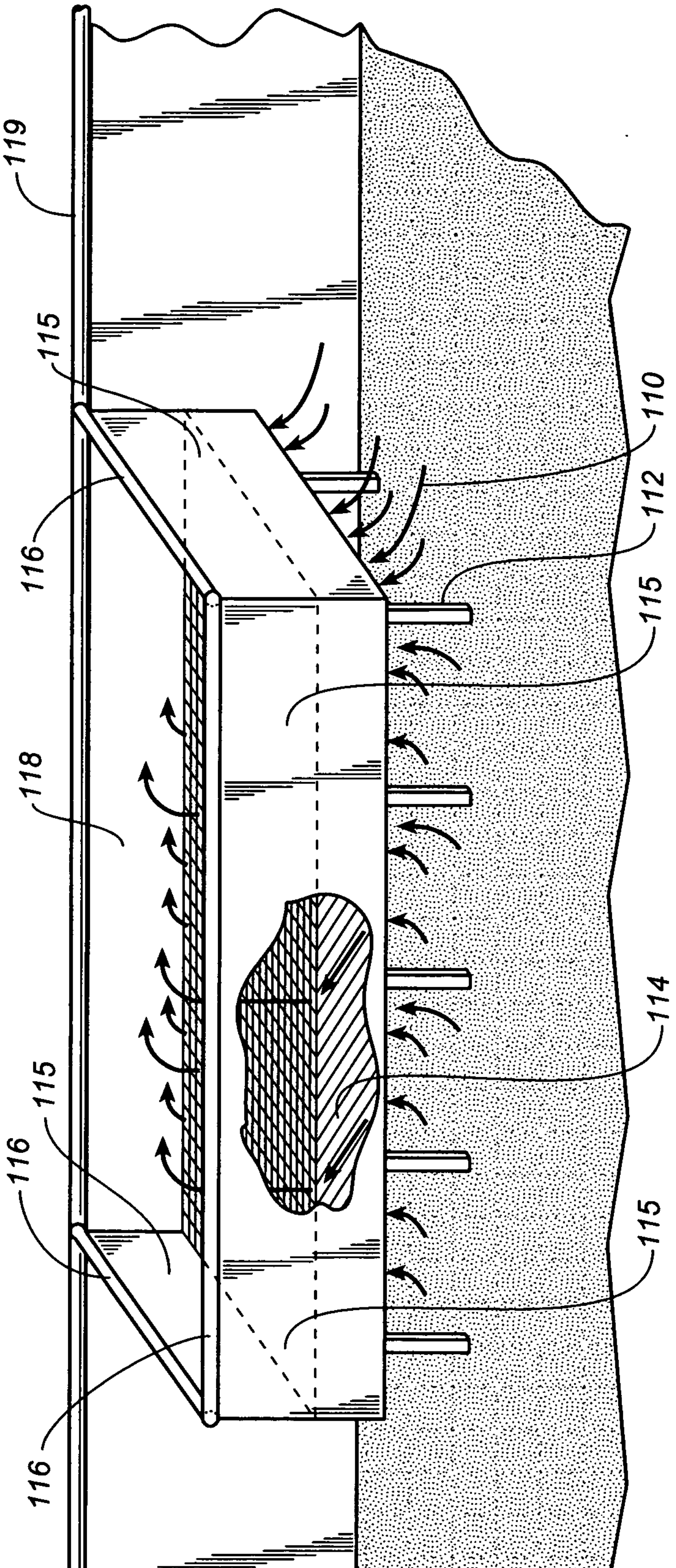

FIG. 8D