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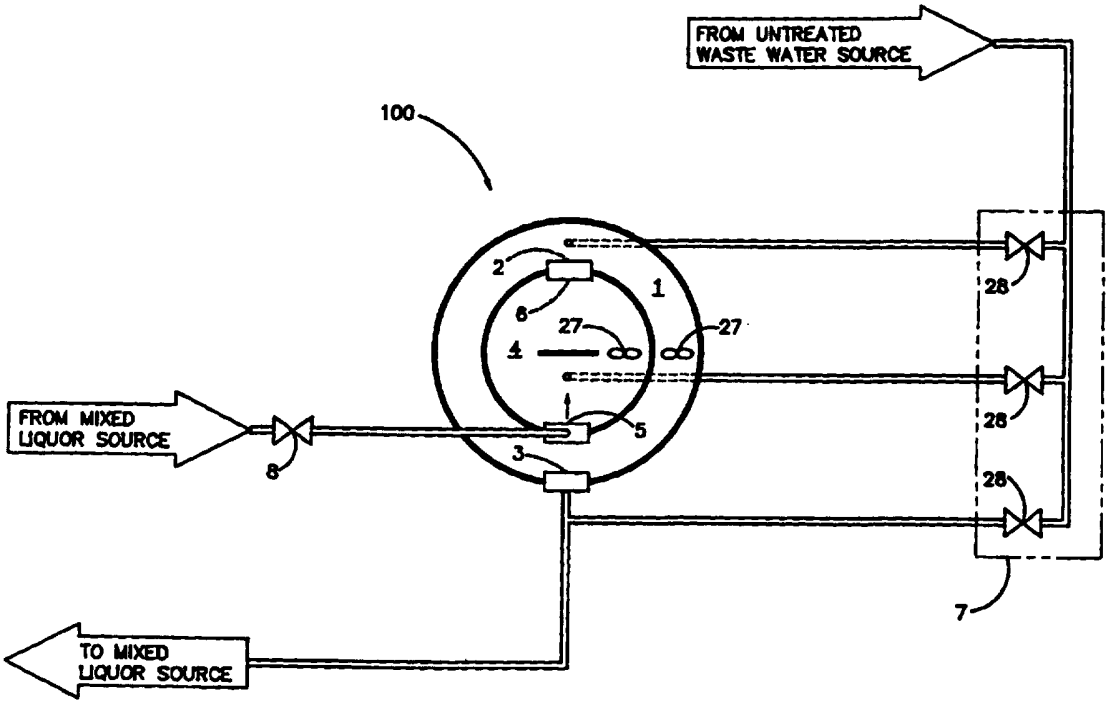

(57) Abstract

A denitrification apparatus and method for use in a wastewater treatment system having a mixed liquor source is disclosed. The apparatus has at least two non-aerated continuous channels (1, 4) connected in series. Wastewater flows from the mixed liquor source into the series of channels and then back to the mixed liquor source. The inlets (2) and outlets (6) for each channel are arranged so that flow is from the upper portion of the channel into the lower portion of the next channel.

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DESCRIPTION
MULTI-CHANNEL
DENITRIFICATION SYSTEM

TECHNICAL FIELD

This invention relates, generally, to wastewater treatment systems; and particularly, to treatment systems which denitrify the wastewater.

BACKGROUND ART

Requirements imposed by numerous governmental agencies have generated several advances in wastewater treatment. Wastewater treatment facilities for the treatment of municipal or industrial waste are also under increasing budgetary pressures to employ systems which have lower capital, operating, and maintenance costs. Therefore, it is desirable to have a wastewater treatment system which minimizes costs while meeting the ever more stringent discharge quality requirements.

The treated discharge from wastewater treatment facilities must meet requirements for BOD (biological oxygen demand material), and in some cases must also meet requirements for maximum amounts of compounds containing nitrogen and phosphorus. The treatment process in which nitrogen is removed from wastewater is known as denitrification. While aerated zones are well-suited for reducing BOD by the use of aerobic organisms, such zones are not well-suited for denitrification. Non-aerated zones, which have a low content of dissolved oxygen (DO), are better suited for denitrification. Such non-aerated, low DO zones are also known in the art as anoxic zones.

In denitrification, activated sludge, also known as mixed liquor, is flowed into an anoxic zones. The mixed liquor contains aerobic organisms which have been growing because they have had fuel (BOD) and oxygen (found as DO in the mixed liquor). The aerobic organisms, upon entering the anoxic zone, find fuel (the BOD) but find little or no

as a source of oxygen. When the aerobic organisms break down the nitrogen compounds to obtain oxygen, nitrogen gas and other harmless bi-products are produced. Different techniques have been used to create anoxic zones. In some systems, an anoxic zone is created in the oxidation ditch, usually just before the mixed liquor is aerated. Such systems are described in U.S. Patent No. 4,290,884 to Mandt, and U.S. Patent No. 5,275,722 to Beard. In other systems, such as that described in U.S. Patent No. 3,764,523 to Stankewich, Jr., aerated treatment vessels are alternated with non-aerated anoxic treatment vessels.

There are at least two difficulties encountered in anoxic zone denitrification. First, it can be difficult to maintain the proper ratio among the three ingredients necessary to sustain the process: aerobic microorganisms (from the mixed liquor), nitrogen compounds (used for the oxygen they contain), and BOD (the fuel for the aerobic microorganisms). Secondly, it is difficult to achieve plug flow. Perfect plug flow is achieved when every unit of wastewater is cycled through a vessel for the exact period of time.

Because of friction along the sides of a vessel and other factors, achieving perfect plug flow is impossible; but it is desirable to come as close as possible to achieving it. The farther a denitrification system is from achieving perfect plug flow, the greater the probability that some wastewater is leaving the anoxic zone without having been properly treated, and some wastewater is remaining in the anoxic zone beyond the length of time necessary for denitrification. Neither of these conditions is desired.

DISCLOSURE OF THE INVENTION

It is an object of the present invention to provide a denitrification system which is compatible with current wastewater treatment systems which have a source of aerated mixed liquor.

Another object of the present invention is to provide

a denitrification system which significantly reduces the nitrogen in the wastewater to within applicable regulatory requirements.

Another object of the present invention is to provide a denitrification system which nearly achieves plug flow.

Another object of the present invention is to provide a denitrification system in which the proper ratio of nitrogen compounds, aerobic microorganisms, and BOD may be maintained by the operator of the system.

Another object of the present invention is to provide a system for which the capital costs are minimized.

Another object of the present invention is to provide a system which minimizes the energy and mechanisms necessary for mixing the anoxic basins.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a plan view of the two-channel embodiment of the invention.

Figure 2 is a plan view of a multi-channel embodiment of the invention.

Figure 3 is a plan view of a multi-channel embodiment of the invention, including a mixed liquor manifold.

Figure 4 is a plan view of an embodiment of the invention, including transfer boxes.

Figure 5 is a sectional view of a preferred embodiment of a transfer box.

Figure 6 is a sectional view of a preferred embodiment of an initial channel inlet.

Figure 7 is a sectional view of a preferred embodiment of a final channel outlet.

Figure 8 is a perspective view of a preferred embodiment of a circulating means.

BEST MODE FOR CARRYING OUT THE INVENTION

Referring to Figure 1, a two-channel embodiment of denitrification apparatus 100 is shown. Denitrification apparatus 100 has two continuous channels fluidly connected

in series; initial channel 4 and final channel 1. Each channel has an inlet for bringing wastewater into the channel and an outlet for flowing water out of the channel. Initial channel inlet 5 is fluidly connected to a mixed liquor source (not shown). The mixed liquor source may be an aerated basin or any other type of source containing aerated activated sludge.

Wastewater flows from the mixed liquor source into initial channel inlet 5. The wastewater is circulated around initial channel 4 by a circulating means 27. The wastewater flows out from initial channel 4 to final channel 1 via initial channel outlet 6 and final channel inlet 2. The wastewater is then circulated around final channel 1 by circulating means 27. The wastewater exits denitrification apparatus 100 via final channel outlet 3, and is returned to the mixed liquor source.

Because the channels are non-aerated, the aerobic organisms brought into denitrification apparatus 100 from the mixed liquor source will exhaust the DO in the wastewater, creating an anoxic environment. The aerobic organisms will then degrade the nitrogen compounds in order to obtain the oxygen they contain. Having been denitrified, the wastewater is returned to the mixed liquor source. In a preferred embodiment the wastewater may be flowed into denitrification apparatus 100 from a low DO point in the mixed liquor source, so as to accelerate the denitrification process.

One or more circulating means 27 are placed deep enough into each channel so that circulating means 27 does not aerate the channel by mixing air into the wastewater. As depicted in FIG. 8, each circulating means 27 is a sealed submersible electric motor 13 which turns a propeller mixer 22. One or more circulating means may be positioned in each channel using one or more mounting rods 35. Although a propeller device is depicted as circulating means 27, one skilled in the art could use a series of paddles which were conveyor or wheel mounted, for which only part of the travel path of the wheel was in the channel; or one could use any

means suitable for causing wastewater to circulate in a continuous channel without aeration. Referring to FIG. 2, a multi-channel embodiment of denitrification apparatus 100 is shown. Similar to the embodiment in FIG. 1, the embodiment shown in FIG. 2 also has non-aerated continuous channels connected in series. Denitrification apparatus 100 depicted in FIG. 2 has initial channel 4, final channel 1, and one or more interim channels 9. Each channel has an inlet for bringing wastewater into the channel and an outlet for flowing wastewater out of the channel.

Initial channel inlet 5 is fluidly connected to a mixed liquor source, and wastewater flows from the mixed liquor source into initial channel inlet 5. The wastewater is circulated around initial channel 4 and flows out from initial channel 4 to an interim channel 9 via initial channel outlet 6 and interim channel inlet 10. The wastewater circulates around each interim channel 9 and leaves each interim channel 9 via interim channel outlet 11. Upon leaving the interim channel which is upstream from final channel 1, the wastewater flows into final channel 1 via final channel inlet 2. After circulating around final channel 1 the wastewater exits denitrification apparatus 100 via final channel outlet 3, and is returned to the mixed liquor source.

One or more circulating means 27 are in each channel, as in the two-channel embodiment, and circulate the wastewater around each channel. As with the two-channel configuration, in a particularly preferred embodiment, the mixed liquor can be flowed from a low DO point in the mixed liquor source.

As shown in FIGS. 1 and 2, denitrification apparatus 100 may include raw sewage manifold 7. Raw sewage manifold 7 is fluidly connected to a source of untreated wastewater (not shown). In the embodiments shown in FIGS. 1 and 2, raw sewage manifold 7 flows untreated wastewater into initial channel 4, final channel 1, and the mixed liquor source. In the embodiments shown, raw sewage manifold 7 includes raw

sewage valves 28 so that the operator of denitrification apparatus 100 can selectively control the flow of untreated wastewater. However, one skilled in the art could eliminate raw sewage valves 28 so that the untreated wastewater flows freely into initial channel 4, final channel 1, and to the mixed liquor source. The untreated wastewater which is flowed into the anoxic environment of the channels will provide BOD to the aerobic organisms, this BOD being in addition to the BOD brought in with the wastewater from the mixed liquor source, thereby sustaining the denitrification process. In the particularly preferred embodiment depicted in FIGS. 1 and 2, the untreated wastewater will be brought into a channel near the bottom of the channel, and in close proximity to the channel inlet and mixed liquor inlet (which will be described later) for each channel.

Also shown in FIGS. 1 and 2 is mixed liquor valve 8, which may be used to selectively control the amount of wastewater flowed from the mixed liquor source into initial channel 4. However, one skilled in the art could practice the invention without mixed liquor valve 8 and simply allow wastewater to flow freely from the mixed liquor source into initial channel 4.

FIG. 3 depicts an embodiment of denitrification apparatus 100 which includes mixed liquor manifold 12. Mixed liquor manifold 12 will include initial channel inlet valve 8 and mixed liquor valves 13. Mixed liquor valves 13 control the flow of wastewater from the mixed liquor source to the channels other than initial channel 4. Using mixed liquor manifold 12, the operator of denitrification apparatus 100 may selectively direct wastewater flowing from the mixed liquor source to each channel. Adjusting the amount of mixed liquor fed to each channel will allow more exact control over the environment in each channel, so as to better achieve the proper ratio of aerobic organisms, BOD, and nitrogen compounds. The mixed liquor will be received into initial channel 4 through initial channel inlet 5, and into the other channels through mixed liquor inlets 36. In a particularly

preferred embodiment, initial channel inlet 5 and mixed liquor inlets 36 will direct the flow of mixed liquor into the lower portion of each channel.

Also depicted in FIG. 3 is another preferred embodiment of raw sewage manifold 7. In the embodiment depicted, raw sewage manifold 7 will include raw sewage valves 28 which control the flow of wastewater from the untreated wastewater source to all of the channels, not just initial channel 4 and final channel 1. Using raw sewage manifold 7, the operator of denitrification apparatus 100 may selectively direct wastewater flowing from the untreated wastewater source to each channel. Adjusting the amount of untreated wastewater fed to each channel will allow more exact control over the environment in each channel, so as to better achieve the proper ratio of aerobic organisms, BOD, and nitrogen compounds. In the particularly preferred embodiment of raw sewage manifold depicted in FIG. 3, the untreated wastewater will be brought into a channel at the bottom of the channel, and in close proximity to the channel inlet and mixed liquor inlet 36 for each channel.

Denitrification apparatus 100 may also consist of one or more non-aerated continuous channels which flow aerated mixed liquor into the lower portion of each channel and out from the upper portion of each channel. This direction of the flow will help the system achieve more ideal plug flow. If there are two or more channels, the channels will be connected in series. In the embodiment depicted in FIG. 4, there are four continuous channels connected in series. The wastewater from the mixed liquor source is received into denitrification apparatus 100 at initial channel inlet 5, and the denitrified wastewater leaves denitrification apparatus 100 at final channel outlet 3. Each channel will have one or more circulating means 27 for circulating the wastewater around each channel.

Transfer boxes 25 are provided for flowing the wastewater from channel to channel. A sectional view of a preferred embodiment of transfer box 25 is depicted in FIG.

5. Each channel has upper portion 20 and lower portion 21. Transfer box 25 is located shared sidewall 14 of two immediately adjacent channels. Transfer box has weir 15 and downstream opening 23 which is formed by transfer box bottom 17 and transfer box downstream wall 18. The wastewater in the upstream channel is contained by weir 15. When the height of the wastewater in the upstream channel reaches the top end 16 of weir 15 the wastewater from upper portion 20 flows over weir top end 16 into transfer box 25. The wastewater next flows out of transfer box 25 through downstream opening 23 into lower portion 21 of the downstream channel.

A sectional view of a preferred embodiment of low inlet 37 is depicted in FIG. 6. Low inlet 37 may be used as the embodiment for initial channel inlet 5 and mixed liquor inlets 36. Using low inlet 37 the aerated mixed liquor will be flowed in through low inlet top opening 29 and out through low inlet bottom opening 30 into bottom portion 21 of a particular channel. A sectional view of a preferred embodiment of final channel outlet 3 is shown in FIG. 7. Depicted is adjustable height weir 31 which has stationary section 32, movable section 33, and adjusting rod 34. A watertight seal is provided between stationary section 32 and movable section 33 so that movable section 33 can be vertically adjusted using adjusting rod 34, to increase or decrease the hydraulic retention of wastewater in from final channel 1. By changing the hydraulic retention, the operator can control the treatment time in denitrification apparatus 100. The wastewater flows from upper portion 21 of final channel 1 over adjustable height weir 31 out to the aerated mixed liquor source.

The multi-channel embodiment of denitrification apparatus 100 may also include recirculating line 38 as depicted in FIG. 3. Because the level of wastewater at final channel outlet 3 is lower than at initial channel 1, recirculating pump 39 will be used to flow wastewater from final channel outlet 3 back to initial channel 1.

Recirculating pump 39 is adapted so as to be adjustably controllable by the operator. Recirculating line 38 and recirculating pump 39 allow the operator to send some or all of the wastewater leaving denitrification apparatus 100 back into the initial channel for further treatment.

Transfer boxes 25 may be integrated into the embodiments of multi-channel denitrification apparatus 100 depicted in FIGS. 1, 2, and 3. As discussed earlier, in a particularly preferred embodiment, the mixed liquor will be flowed into each channel in close proximity to the inlet from the immediately adjacent channel, and the inlet from the raw sewage manifold. These inlets will be placed on the opposite side of the channel from the outlet. With this arrangement of inlets and outlets, a particle of wastewater will move in a spiraling path, from the bottom portion of the channel at one point, to the top portion at a point 180° away from the inlet, nearly achieving ideal plug flow. This plug flow is accomplished while giving three necessary ingredients for denitrification (aerobic organisms, BOD, and nitrogen compounds) the maximum time to react.

There are of course other alternate embodiments which are obvious from the foregoing descriptions of the invention, which are intended to be included within the scope of the invention, as defined by the following claims.

CLAIMS

What Is Claimed Is:

1. An apparatus for the denitrification of wastewater, for use in a wastewater treatment system having a mixed liquor source, comprising: two or more non-aerated continuous channels, said channels being fluidly connected in a series, each said channel having an inlet, an outlet, and a circulating means for circulating said wastewater in said channel; said inlet of an initial channel of said series being fluidly connected to said mixed liquor source, said initial channel inlet being adapted such that said wastewater flows from said mixed liquor source to said initial channel, said outlet of a final channel of said series being fluidly connected to said mixed liquor source, said final channel outlet being adapted such that said wastewater flows from said final channel to said mixed liquor source.

2. The apparatus in claim 1, further comprising a raw sewage manifold fluidly connecting an untreated wastewater source to said channels and said mixed liquor source.

3. The apparatus in claim 2, wherein said raw sewage manifold is selectively controllable.

4. The apparatus in claim 1, 2, or 3, wherein said initial channel inlet flows said wastewater from a low DO point in said mixed liquor source.

5. The apparatus in claim 4, wherein said initial channel inlet is adjustably controllable.

6. The apparatus in claim 5, wherein said continuous channels are in a concentric arrangement.

7. An apparatus for the denitrification of wastewater, for use in a wastewater treatment system having a mixed liquor source, comprising: one or more non-aerated continuous channels, said channels being fluidly connected in a series if there are two or more of said channels, each said channel comprising:

(i) an upper portion;

(ii) a lower portion;

(iii) an inlet, said inlet being adapted such that said

wastewater is received into said lower portion of said channel;

(iv) an outlet, said outlet being adapted such that said wastewater is flowed out of said upper portion of said channel; and

(v) a circulating means for circulating said wastewater in said channel;

said inlet of an initial channel of said series being fluidly connected to said mixed liquor source, said initial channel inlet being adapted such that said wastewater flows from said mixed liquor source to said initial channel, said outlet of a final channel of said series being fluidly connected to said mixed liquor source, said final channel outlet being adapted such that said wastewater flows from said final channel to said mixed liquor source.

8. The apparatus in claim 7, further comprising a raw sewage manifold fluidly connecting an untreated wastewater source to one or more of said channels and said mixed liquor source.

9. The apparatus in claim 8, wherein said raw sewage manifold is selectively controllable.

10. The apparatus in claims 7, 8, or 9, wherein each said channel further comprises vertical sidewalls, said channels being adapted such that immediately adjacent upstream and downstream channels in said series share a sidewall, said upstream channel outlet and said downstream channel inlet together comprising a transfer box located in said shared sidewall, said transfer box comprising:

(1) a weir having a top end, said top end of said weir extending into said upper portion of said upstream channel, said weir being adapted such that wastewater flows from said upper portion of said upstream channel, over said weir top end, into said transfer box; and

(2) a transfer box bottom and a channel inlet wall forming a downstream opening, said downstream opening being adapted such that said wastewater flows from said transfer box into said lower

portion of said downstream channel.

11. The apparatus in claim 10, wherein said continuous channels are in a concentric arrangement.

12. The apparatus in claim 11, wherein said initial channel is the most radially inward channel, and said final channel is the most radially outward channel, in said concentric arrangement.

13. The apparatus in claim 12, wherein said concentrically arranged channels are arranged radially inward from a concentrically arranged aerated mixed liquor continuous channel. 14. The apparatus in claim 13, further comprising a recirculating line, and a recirculating pump in fluid connection with said recirculating line, said recirculating line and said recirculating pump being adapted so that wastewater leaving said denitrification apparatus at said final channel outlet may be flowed to said initial channel.

15. The apparatus in claims 1 or 7, further comprising a selectively controllable mixed liquor manifold fluidly connecting a low DO point in said mixed liquor source to said inlet in each said channel; said mixed liquor manifold being adapted such that the flow of said wastewater from said low DO point in said mixed liquor source may be selectively directed to each said channel.

16. A method for the denitrification of wastewater comprising:

(1) flowing said wastewater from a mixed liquor source to an initial non-aerated continuous channel in a series of two or more fluidly connected non-aerated continuous channels,

(2) circulating said wastewater in each said channel; and

(3) flowing said wastewater from a final channel of said series of channels to said mixed liquor source.

17. The method in claim 16, wherein said wastewater is flowed into a bottom portion of each said channel, and out from an upper portion of each said channel.

18. The method in claim 17, further comprising flowing

wastewater from an untreated wastewater source to said first channel, said last channel, and said mixed liquor source.

19. The method in claim 16, 17, or 18, wherein said wastewater from said mixed liquor source is flowed from a low DO point in said mixed liquor source.

20. The method in claim 19, further comprising adjustably controlling the flow of said mixed liquor into said initial channel.

21. The method in claim 20, further comprising flowing wastewater from said mixed liquor source to each said channel and selectively controlling the amount of said wastewater from said mixed liquor source flowed to each channel.

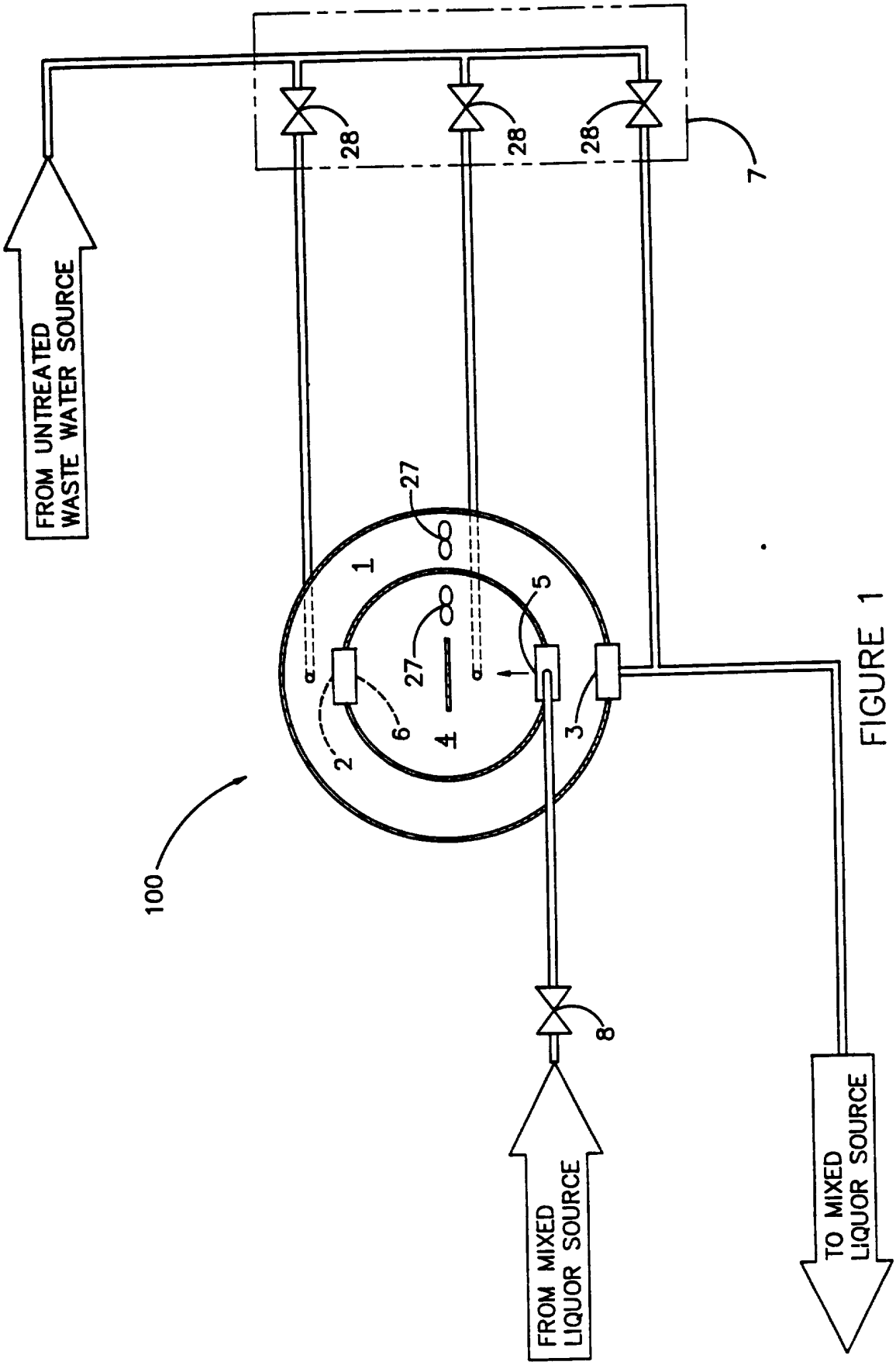
22. The method in claim 18, further comprising flowing wastewater from an untreated wastewater source into each said channel.

22. A method for the denitrification of wastewater comprising:

(1) flowing said wastewater from a mixed liquor source into a bottom portion of a non-aerated continuous channel,

(2) circulating said wastewater in said channel; and

(3) flowing said wastewater out from an upper portion of said channel to said mixed liquor source.


FROM UNTREATED WASTE WATER SOURCE
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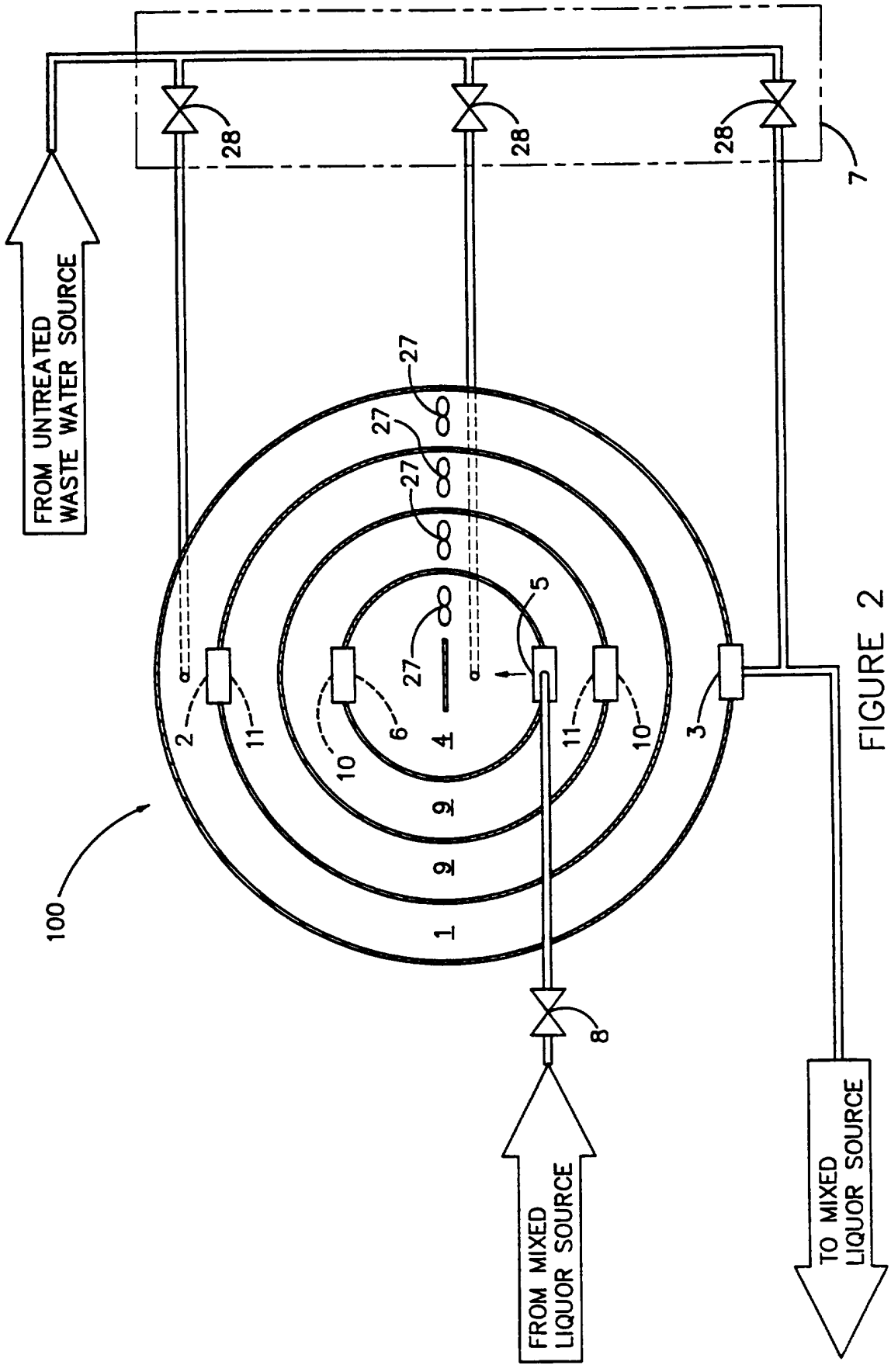
FROM MIXED LIQUOR SOURCE
TO MIXED LIQUOR SOURCE

FIGURE 1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FROM MIXED LIQUOR SOURCE
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FIGURE 2

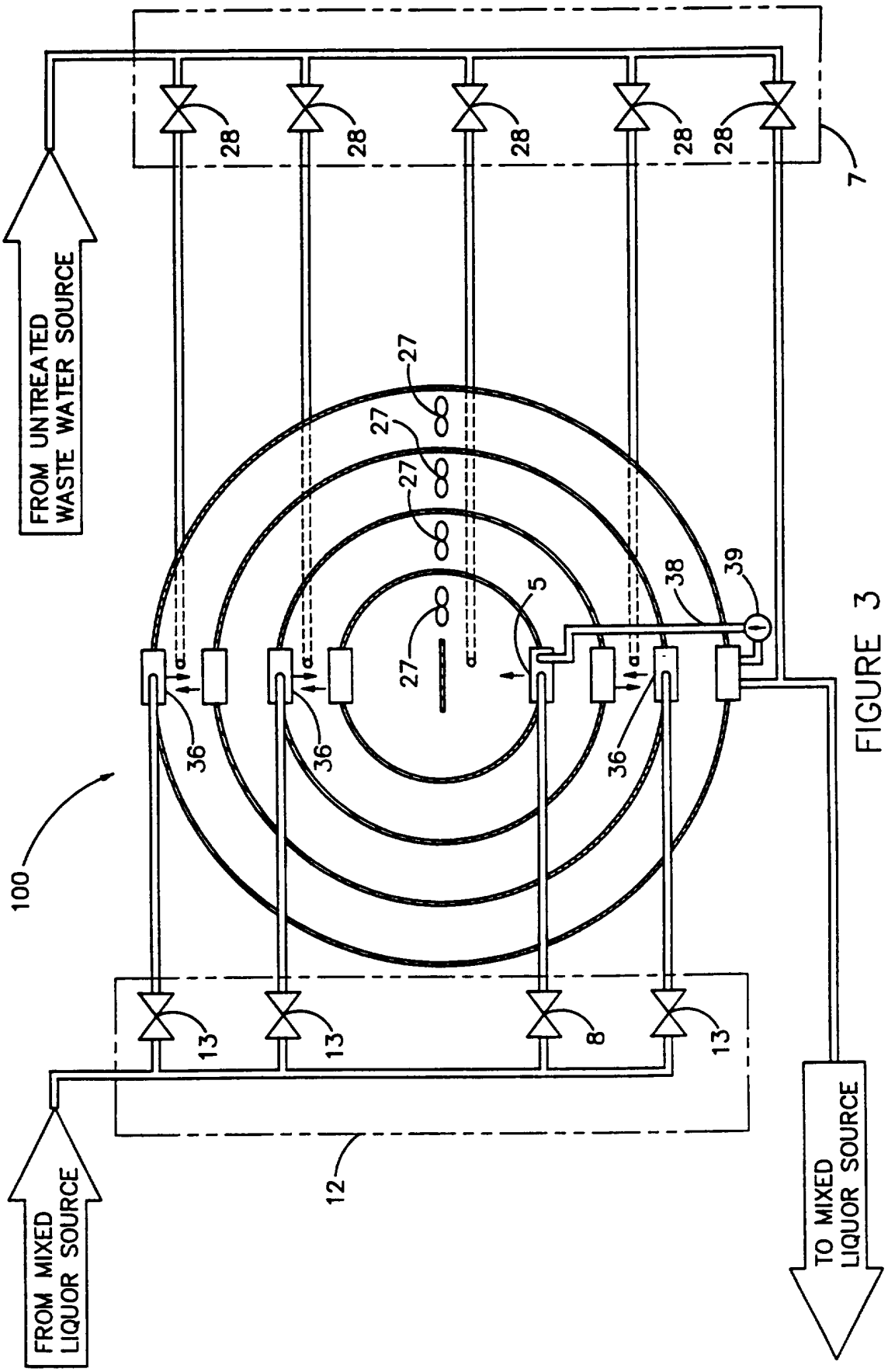
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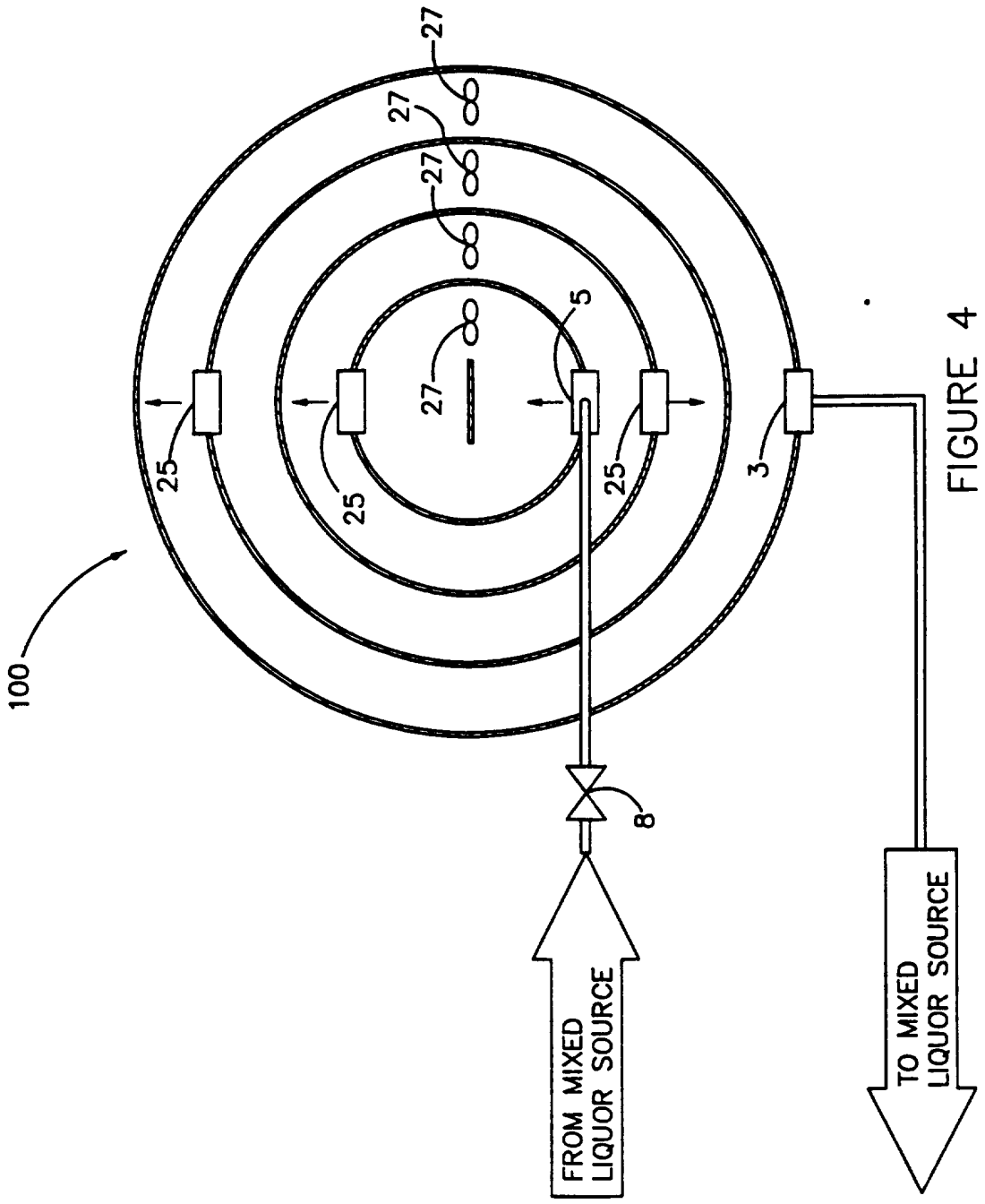
FIGURE 3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FROM MIXED LIQUOR SOURCE
TO MIXED LIQUOR SOURCE

FIGURE 4

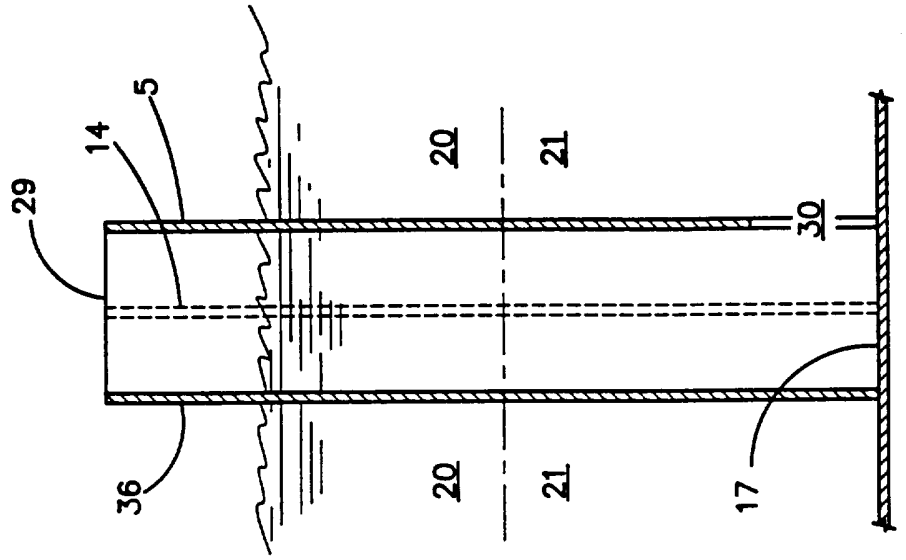

FIGURE 6

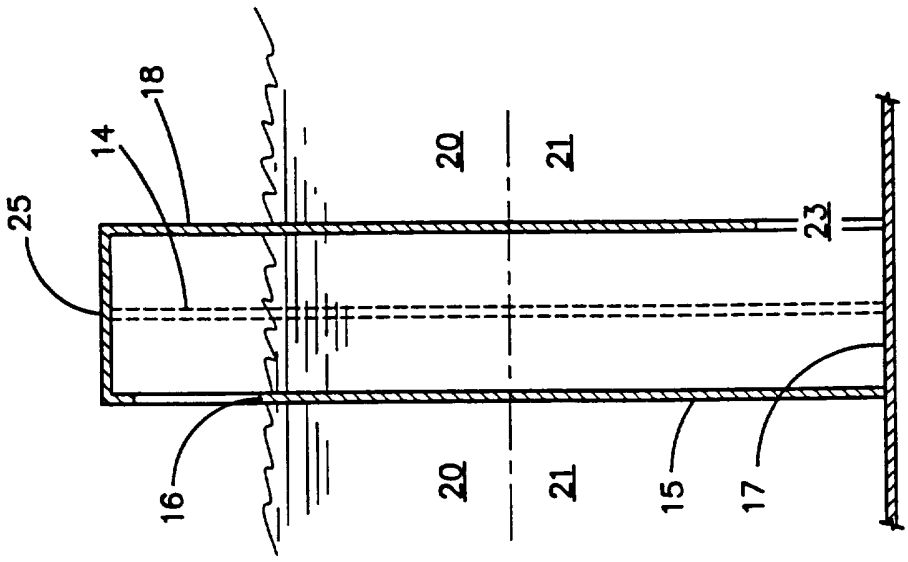

FIGURE 5

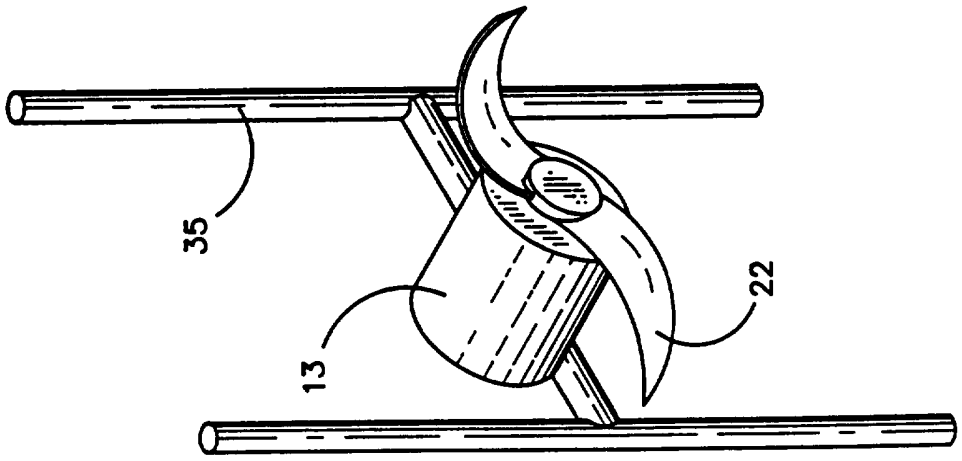

FIGURE 8

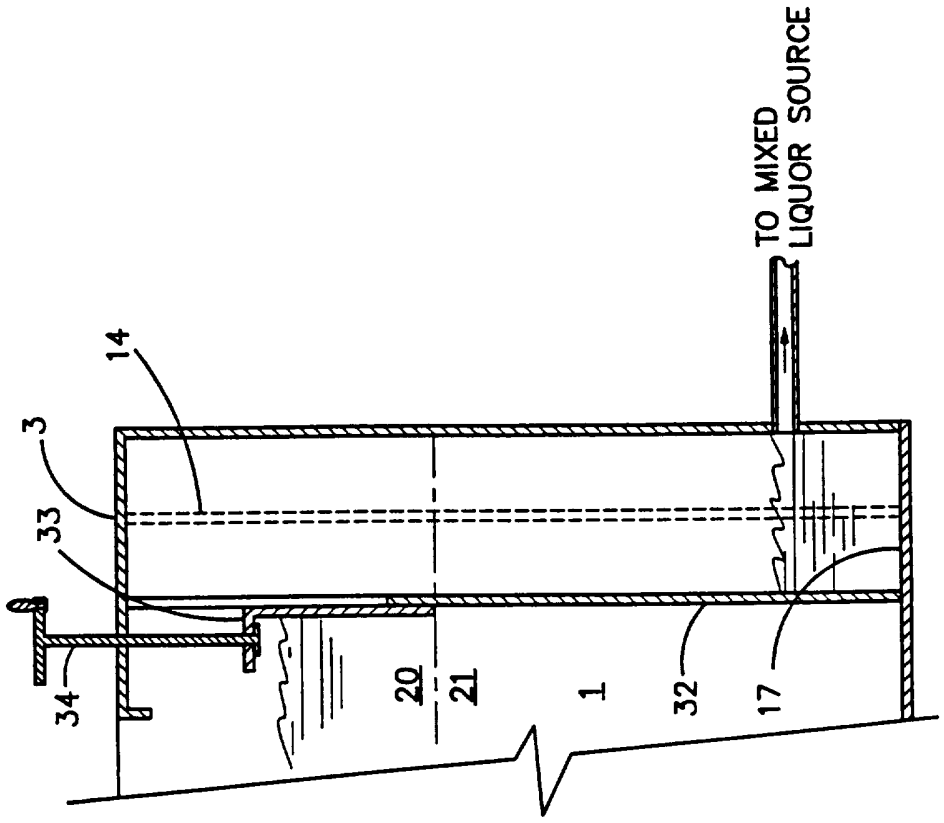

FIGURE 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/15049

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :CO2F 3/30
US CL :210/605, 607, 630, 195.1, 903, 926
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 210/605, 607, 621, 629, 630, 194, 195.1, 255, 256, 259, 903, 926

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 4,183,809 (KLAPWIJK ET AL) 15 January 1980, see figure 1.	1-22
Y	US, A, 4,290,884 (MANDT) 22 September 1981, see figure 4.	1-22
Y	US, A, 4,159,243 (OKEY) 26 June 1979, see figure 1.	1-22
Y	US, A, 5,192,442 (PICCIRILLO ET AL) 09 March 1993, see figure 1.	7-14, 17, 18, 21, 22
Y	US, A, 4,975,197 (WITTMANN ET AL) 04 December 1990, see figure 1.	6, 11-14

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of mailing of the international search report
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