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(54) **Title**: METHOD OF RECYCLING CENTRATE TO GENERATE STEAM IN A STRIPPER

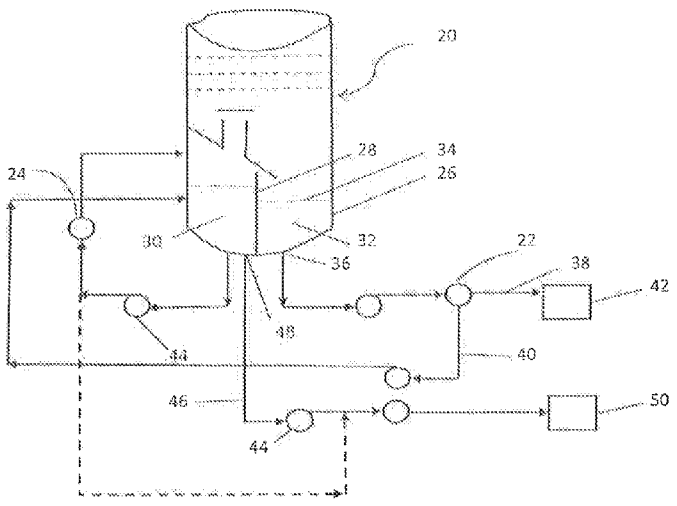


FIG. 1

(57) **Abstract**: A method of recycling centrate in a distillation process to purify a component of a fermentation broth. The method includes segregating a portion of the fermentation broth to form a decreased solids stream and an increased solids stream, heating the decreased solids stream, and separating the component from the fermentation broth by the heat from the decreased solids stream. An apparatus for purifying the component of the fermentation broth includes a distillation column with a bottom; a liquid/solid separation device in fluid communication with the distillation column; an indirect heat exchanger in fluid communication with the distillation column and the liquid/solid separation device; and a partition within the bottom of the distillation column to form a decreased solids zone and an increased solids zone.

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METHOD OF RECYCLING CENTRATE TO GENERATE STEAM IN A STRIPPER

Background

Technical Field

The invention relates to a method of purifying a component of a fermentation broth, which generates steam that can be recycled for further use in the purification process. Aspects of the invention relate to an apparatus that includes a distillation column having a partition within the bottom.

Discussion of Related Art

Renewable materials can be derived from biotic feedstocks in a process that converts available sugars into desirable molecules, such as biofuels and biochemicals. Biotic feedstocks include polysaccharide-containing plants, such as lignocellulosic biomass, sugarcane, corn, wheat, beets, and others. Processes for converting feedstocks into renewable materials typically involve fermentation and distillation. For example, fermentation can produce alcohols, organic acids, hydrocarbons, hydrogen, proteins or mixtures of any of these materials. After fermentation, the resulting fluids can be distilled in order to separate the fermentation products from the water and residual solids.

Distillation processes typically include a beer stripper operation in which liquids and solids are circulated through reboilers to generate stripping steam requirements. However, the liquids generally contain a relatively high concentration of solids. The presence of a high amount of solids causes fouling and plugging of the tubes in the reboilers, which leads to erosion of the tubes. Consequently, the high solids content results in a system that is high maintenance. Due to the need to frequently unclog and/or replace tubes, the overall distillation process is unstable and unreliable.

There is thus a need and desire for a distillation process that can generate a liquid stream having a significantly reduced amount of solids.

Summary

The invention is directed to a method of recycling centrate in a distillation process to purify a component of a fermentation broth, as well as an apparatus for purifying the component of the fermentation broth. Compared to conventional distillation processes, the processes of the invention are considerably more reliable and more stable and result in an improved recovery of the purified component. The purified component may be ethanol or other alcohols, for example.

A fermentation broth, as used herein, suitably includes the component to be purified, water or centrate, and fermentative solids. According to certain embodiments, the fermentation broth may be derived from a feedstock that includes, for example, a lignocellulosic material, sugarcane, corn, wheat, and/or beets.

According to some embodiments, a method of purifying a component of a fermentation broth includes segregating a portion of the fermentation broth to form a decreased solids stream and an increased solids stream. More particularly, the decreased solids stream has a lower concentration of solids compared to the fermentation broth, while the increased solids stream has a greater concentration of solids compared to the fermentation broth. After segregating the portion of the fermentation broth, the decreased solids stream is heated, and the heat separates the component from the fermentation broth. Additionally, steam may form from heating the decreased solids stream, and the steam may be directed back into the segregated portion of the fermentation broth that includes the decreased solids stream.

According to some embodiments, a method of recycling centrate in a distillation process may include directing a fermentation broth into a beer stripper, removing a portion of the fermentation broth through a bottom outlet of the beer stripper, separating the portion of the fermentation broth into a stream of high solids concentration material and a stream of low solids concentration material, directing the stream of high solids concentration material to a boiler, directing the stream of low solids concentration material through a reboiler to produce steam, separating the component from the primary centrate in the stream of low solids concentration material using heat from the reboiler, and directing the steam into an isolated section of the stripper.

In certain embodiments, the method may also include removing a stream of secondary centrate from a bottom outlet of the segregated or isolated section of the fermentation broth that includes the decreased solids stream, pumping the stream of secondary centrate through a reboiler to produce steam, and directing the steam back into the segregated portion of the fermentation broth that includes the decreased solids stream. Additionally, the method may include removing excess secondary centrate from a second outlet of the segregated portion of the fermentation broth that includes the decreased solids stream and sending the excess secondary centrate to a wastewater treatment plant. Furthermore, the method may include separating the stream of secondary centrate into a first stream and a second stream, pumping the first stream through a reboiler to produce steam and directing the steam back into the

segregated portion of the fermentation broth that includes the decreased solids stream, and directing the second stream of secondary centrate to a wastewater treatment plant.

Following the distillation process, according to some embodiments, the method may further include removing a first stream of rectified centrate from a first bottom outlet of a rectifier, directing the first stream of rectified centrate through a reboiler to produce steam, and directing the steam into an upper inlet of the rectifier. The method may also include removing a second stream of rectified centrate from a second bottom outlet of a rectifier and directing the second stream of rectified centrate to the stream of low solids concentration material of the fermentation broth.

Various techniques may be used to separate the fermentation broth into multiple streams. For example, a filter, a centrifuge, or a filter press may be used to achieve separation.

According to some embodiments, an apparatus for purifying a component of a fermentation broth includes a distillation column with a bottom, a liquid/solid separation device in fluid communication with the distillation column, an indirect heat exchanger in fluid communication with the distillation column and the liquid/solid separation device, and a partition within the bottom of the distillation column to form a decreased solids zone and an increased solids zone.

The indirect heat exchanger may include a thermosyphon, for example.

The liquid/solid separation device may include a filter, a centrifuge, or a filter press, for example.

Brief Description of the Drawings

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with the description, serve to explain the features, advantages, and principles of the invention. In the drawings:

FIG. 1 is a diagram illustrating one embodiment of a distillation process.

FIG. 2 is a diagram illustrating a conventional distillation process.

FIG. 3 is a diagram illustrating another embodiment of a distillation process.

Detailed Description

The invention is directed to a method of recycling centrate in a distillation process to purify a component of a fermentation broth, as well as an apparatus for purifying the component of the fermentation broth. Compared to conventional distillation processes, the processes of the invention are considerably more reliable and more stable and result in an improved recovery of the purified component.

The methods described herein may be used to purify components such as ethanol or other renewable materials, for example. Other components that may be purified according to these methods include iso butanol, iso amyl alcohol, and furfurol.

A fermentation broth, as used herein, suitably includes the component to be purified, centrate including water, and fermentative solids. According to certain embodiments, the fermentation broth may be derived from a feedstock that includes, for example, a lignocellulosic material, sugarcane, corn, wheat, and/or beets.

As used herein, the term "renewable material" preferably refers to a substance and/or an item that has been at least partially derived from a source and/or a process capable of being replaced at least in part by natural ecological cycles and/or resources. Renewable materials may broadly include, for example, chemicals, chemical intermediates, solvents, adhesives, lubricants, monomers, oligomers, polymers, biofuels, biofuel intermediates, biogasoline, biogasoline blendstocks, biodiesel, green diesel, renewable diesel, biodiesel blend stocks, biodistillates, biochar, biocoke, renewable building materials, and/or the like. As a more specific example, the renewable material may include, without being limited to, any one or more of the following: ethanol, n-butanol, isobutanol, 2-butanol, fatty alcohols, isobutene, isoprenoids, triglycerides, lipids, fatty acids, lactic acid, acetic acid, propanediol, butanediol. In certain embodiments, the renewable material may include one or more biofuel components. For example, the renewable material may include a simple alcohol, such as ethanol, butanol, or isobutanol, or lipids.

"Lignocellulosic" and "lignocellulose" preferably broadly refer to materials containing cellulose, hemicellulose, lignin, and/or the like, such as may be derived from plant material and/or the like. Lignocellulosic material may include any suitable material, such as sugarcane, sugarcane bagasse, energy cane, energy cane bagasse, rice, rice straw, corn, corn stover, corn cobs, wheat, wheat straw, maize, maize stover, sorghum, sorghum stover, sweet sorghum, sweet sorghum stover, Arundo, cotton remnant, sugar beet, sugar beet pulp, soybean, rapeseed, jatropha, switch grass, energy grass, miscanthus, Napier grass, other grasses, and hybrids of any of these materials. Lignocellulosic material may also include, in general, grasses, leaves, legumes, forbs, cacti, timber, wood chips, softwoods such as pine and poplar, hardwoods such as eucalyptus, oak, and hickory, forest litter, wood waste, sawdust, paper, paper mill residue, paper waste, agricultural residue, municipal solid waste, any other suitable biomass material, and/or the like. Lignocellulosic feedstocks used in the methods and systems described herein typically include a hemicellulose material, a cellulose

material, and a lignin material. In certain embodiments, the lignocellulosic feedstocks may also include an unbound carbohydrate material.

"Centrate" preferably broadly refers to fluid removed in a liquid/solid separation procedure. More specifically, the centrate may be the undesirable liquid portion separated from a desirable component following a separation procedure.

One embodiment of a distillation process in accordance with the invention is illustrated in FIG. 1. The distillation process begins in a distillation column, or beer stripper 20. A liquid/solid separation device 22 is in fluid communication with the distillation column 20. The liquid/solid separation device 22 may include a filter, a centrifuge, a filter press, or any other suitable device that can be used to separate liquids and solids. An indirect heat exchanger 24, such as a thermosyphon, is in fluid communication with both the distillation column 20 and the liquid/solid separation device 22. Within a bottom portion 26 of the distillation column 20 there is a partition 28 that segregates the fermentation broth 34 into a decreased solids zone 30 and an increased solids zone 32. As used herein, the terms "bottom" and "bottom portion" refer to a portion within a lower half of the distillation column, not necessarily at the absolute bottom. The decreased solids zone 30 has a lower solids concentration than the increased solids zone 32. For instance, the solids concentration of the decreased solids zone 30 may be at least 5% less, or at least 10% less, or at least 15% less than the solids concentration of the increased solids zone 32. Of course, the solids concentration of both the decreased solids zone 30 and the increased solids zone 32 varies during the distillation process, so these differences are merely an approximation.

By separating the decreased solids zone 30 and the increased solids zone 32, the beer stripper operation is improved, and a safer and more reliable operation is created. More particularly, in carrying out the distillation process, the fermentation broth 34 is directed into the distillation column or beer stripper 20. A portion of the fermentation broth 34 is then removed from the increased solids zone 32 through a bottom outlet 36 of the distillation column or beer stripper 20. As used herein, the term "bottom outlet" refers to an outlet within a lower half of a device or element, not necessarily located at the absolute bottom of the device or element.

The liquid/solid separation device 22 separates the portion of the fermentation broth 34 into a stream of high solids concentration material 38 and a stream of low solids concentration material 40. The stream of high solids concentration material 38 may be directed to a boiler 42 in order to further break down the solid material. The stream of low solids concentration material 40 may be directed through a reboiler 44 to produce steam. The

heat from the reboiler 44 may be used to separate the component from the primary centrate in the stream of low solids concentration material 40. The purified component has improved recovery compared to conventional distillation processes due to the separation of the fermentation broth 34 into the decreased solids zone 30 and the increased solids zone 32, which allows for continued separation of the component from the primary centrate as the stream of low solids concentration material 40 passes from the decreased solids zone 30 and back through the reboiler 44. Steam from the primary centrate may be recycled by directing the steam into an isolated section of the distillation column 20, namely, into the decreased solids zone 30 defined by the partition 28.

The process may further include removing a stream of secondary centrate 46 from a bottom outlet 48 of the isolated section of the distillation column or beer stripper 20 and pumping the stream of secondary centrate 46 through another reboiler 44 to produce steam. The steam may be directed back into the isolated section of the distillation column or beer stripper 20, while excess secondary centrate may be removed to a wastewater treatment plant 50.

A conventional distillation process is illustrated in FIG. 2. Notably, there is no partition 28 in the distillation column or beer stripper 120. Instead, a portion of fermentation broth 134 is removed from the distillation column 120 through a bottom outlet 136. After passing through a heat exchanger 124, the fermentation broth 134 is directed to a liquid/solid separation device 122, which separates the portion of the fermentation broth 134 into a stream of high solids concentration material 138 and a stream of, essentially, centrate 139. The stream of high solids concentration material 138 may be directed to a boiler 142 in order to further break down the solid material. The centrate 139 may be removed to a wastewater treatment plant 150. More of the fermentation broth 134 is pumped out of the distillation column 120 from another bottom outlet 148 using a pump 152, and then directed through a reboiler 144 to produce steam, which is pumped back into the distillation column 120. Because the stream of fermentation broth 134 that is pumped through the reboiler 144 does not have a reduced concentration of solids, the reboiler 144 is highly susceptible to fouling and clogging. Thus, the system requires considerable maintenance and cleaning. Without sufficient maintenance, the system is unstable and unreliable due to frequent breakdowns.

Another embodiment of a distillation process in accordance with the invention is illustrated in FIG. 3. In this embodiment, much of the apparatus and process is the same as illustrated in FIG. 1, with like elements represented by the same reference numerals as in FIG. 1. If batch distillation is desired, one or more rectifiers 60 may be included in the

process. A first stream 62 of rectified centrate may be removed from a bottom outlet 64 of the rectifier 60, directed through a reboiler 44 to produce steam, and then directed into an upper inlet 66 of the rectifier 60. A second stream 68 of rectified centrate may be removed from another bottom outlet 70 of the rectifier 60 and directed to the stream of low solids concentration material 40 of the fermentation broth 34.

The processes and equipment described herein use centrate, or a portion of the centrate, from the liquid solids separation and/or from the rectifier to generate stripping steam in the distillation column. In doing so, improved ethanol recovery is achieved. Furthermore, segregating the fermentation broth within the distillation column into an increased solids zone and a decreased solids zone, and passing a liquid stream with a significantly reduced amount of solids through the reboilers greatly reduces or eliminates fouling and clogging in the reboilers. Thus, compared to conventional distillation processes, the processes described herein are more reliable and more stable, and require less maintenance.

It will be apparent to those skilled in the art that various modifications and variations can be made in the disclosed structures and methods without departing from the scope or spirit of the invention. Particularly, descriptions of any one embodiment can be freely combined with descriptions or other embodiments to result in combinations and/or variations of two or more elements or limitations. Other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be considered exemplary only, with a true scope and spirit of the invention being indicated by the following claims.

What is claimed is:

1. A method of recycling centrate in a distillation process while purifying a component of a fermentation broth, wherein the fermentation broth comprises the component and a primary centrate, the method comprising:

directing the fermentation broth into a beer stripper;

separating a portion of the fermentation broth into a stream of high solids concentration material and a stream of low solids concentration material; and

separating the component from the primary centrate in the stream of low solids concentration material using heat from a reboiler.

2. The method of claim 1, further comprising:

removing the portion of the fermentation broth through a bottom outlet of the beer stripper.

3. The method of claim 1, further comprising:

directing the stream of high solids concentration material to a boiler.

4. The method of claim 1, further comprising:

directing the stream of low solids concentration material through the reboiler to produce steam.

5. The method of claim 4, further comprising:

directing the steam into an isolated section of the stripper.

6. The method of claim 5, further comprising:

removing a stream of secondary centrate from a bottom outlet of the isolated section of the stripper;

pumping the stream of secondary centrate through a reboiler to produce steam; and

directing the steam back into the isolated section of the stripper.

7. The method of claim 6, further comprising removing excess secondary centrate from a second outlet of the isolated section of the stripper to a wastewater treatment plant.

8. The method of claim 6, further comprising:

separating the stream of secondary centrate into a first stream and a second stream;

pumping the first stream of secondary centrate through a reboiler to produce steam and directing the steam back into the isolated section of the stripper; and

directing the second stream of secondary centrate to a wastewater treatment plant.

9. The method of claim 1, further comprising:

removing a first stream of rectified centrate from a first bottom outlet of a rectifier;

directing the first stream of rectified centrate through a reboiler to produce steam; and

directing the steam into an upper inlet of the rectifier.

10. The method of claim 9, further comprising removing a second stream of rectified centrate from a second bottom outlet of a rectifier and directing the second stream of rectified centrate to the stream of low solids concentration material of the fermentation broth.

11. The method of claim 1, comprising separating the portion of the fermentation broth into the stream of high solids concentration material and the stream of low solids concentration material using at least one of the group consisting of a filter, a centrifuge, and a filter press.

12. The method of claim 1, wherein the fermentation broth is derived from a feedstock selected from the group consisting of a lignocellulosic material, sugarcane, corn, wheat, beets, and combinations thereof.

13. The method of claim 1, wherein the component comprises ethanol.

14. A method of purifying a component of a fermentation broth, wherein the fermentation broth comprises the component, water, and fermentative solids, the method comprising:

i) segregating a portion of the fermentation broth to form a decreased solids stream versus the fermentation broth and an increased solids stream versus the fermentation broth;

ii) heating the decreased solids stream; and

iii) separating the component from the fermentation broth by the heat from the decreased solids stream.

15. The method of claim 14, wherein steam forms from heating the decreased solids stream; and further comprising directing the steam into the segregated portion of the fermentation broth that includes the decreased solids stream.

16. The method of claim 15, further comprising:

removing a stream of secondary centrate from a bottom outlet of the segregated portion of the fermentation broth that includes the decreased solids stream;

pumping the stream of secondary centrate through a reboiler to produce steam; and

directing the steam back into the segregated portion of the fermentation broth that includes the decreased solids stream.

17. The method of claim 16, further comprising removing excess secondary centrate from a second outlet of the segregated portion of the fermentation broth that includes the decreased solids stream, to a wastewater treatment plant.

18. The method of claim 16, further comprising:

separating the stream of secondary centrate into a first stream and a second stream;

pumping the first stream of secondary centrate through a reboiler to produce steam and directing the steam back into the segregated portion of the fermentation broth that includes the decreased solids stream; and

directing the second stream of secondary centrate to a wastewater treatment plant.

19. The method of claim 14, comprising segregating the portion of the fermentation broth to form the decreased solids stream and the increased solids stream using at least one of the group consisting of a filter, a centrifuge, and a filter press.

20. The method of claim 14, wherein the fermentation broth is derived from a feedstock selected from the group consisting of a lignocellulosic material, sugarcane, corn, wheat, beets, and combinations thereof.

21. The method of claim 14, wherein the component comprises ethanol.

22. An apparatus for purifying a component of a fermentation broth, wherein the fermentation broth comprises the component, water, and fermentative solids, the apparatus comprising:

a distillation column with a bottom; and

a partition within the bottom of the distillation column to form a decreased solids zone and an increased solids zone.

23. The apparatus of claim 22, further comprising:

a liquid/solid separation device in fluid communication with the distillation column.

24. The apparatus of claim 23, further comprising:

an indirect heat exchanger in fluid communication with the distillation column and the liquid/solid separation device;

25. The apparatus of claim 24, wherein the indirect heat exchanger comprises a thermosyphon.

26. The apparatus of claim 23, wherein the liquid/solid separation device comprises at least one of the group consisting of a filter, a centrifuge, and a filter press.

27. The apparatus of claim 22, wherein the fermentation broth is derived from a feedstock selected from the group consisting of a lignocellulosic material, sugarcane, corn, wheat, beets, and combinations thereof.

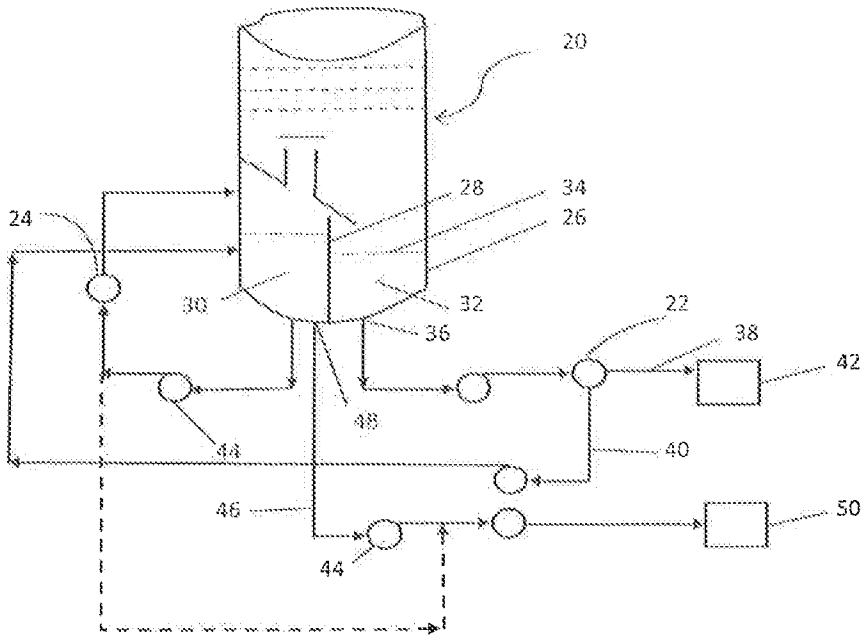


FIG. 1

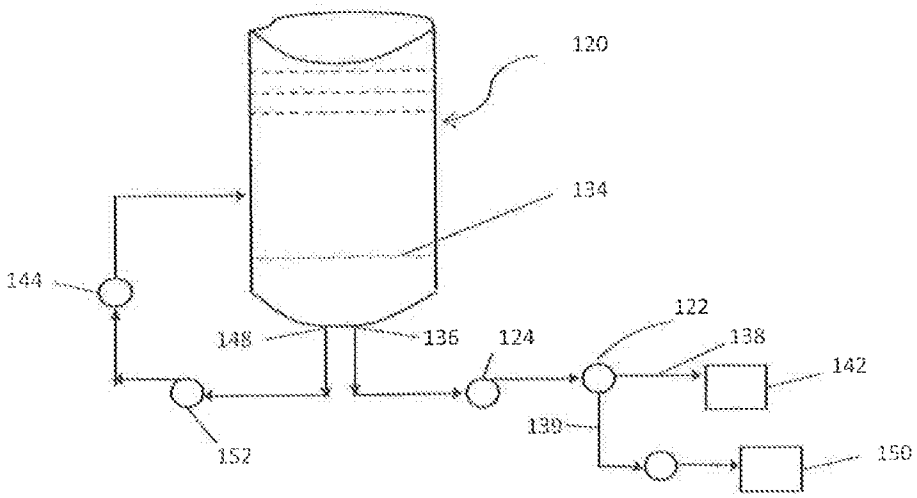


FIG. 2
(Prior Art)

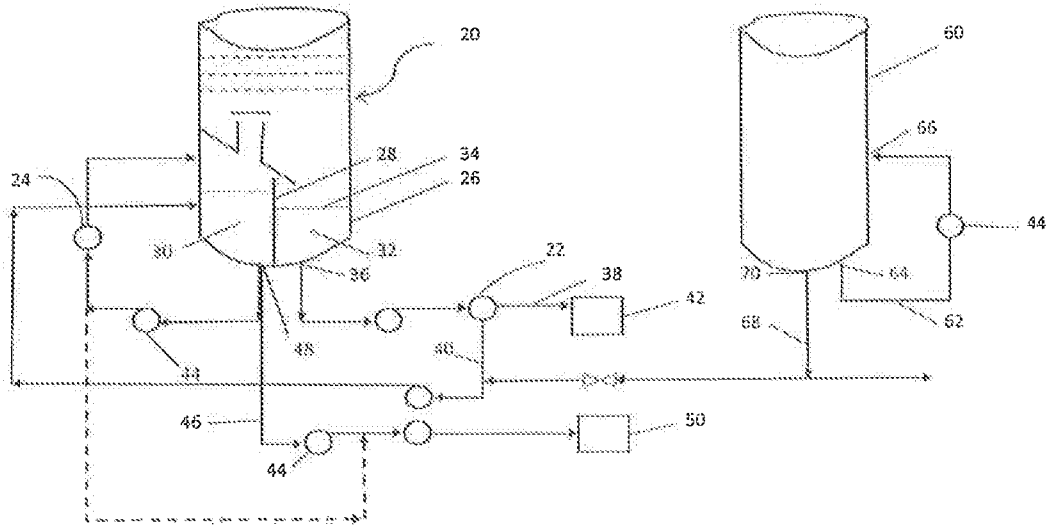


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/024380

A. CLASSIFICATION OF SUBJECT MATTER
INV. B01D3/00 C12G3/12 C12P7/06 B01D3/14
ADD.

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)
B01D C12G C12P

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)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	US 4 327 184 A (JOHNSON STEVEN A ET AL) 27 April 1982 (1982-04-27) column 3, line 60 - column 4, line 16; figure 1 abstract; figure 1 column 5, line 45 - column 6, line 2	1-27
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X	US 6 759 560 B2 (GUTH JOSEF [DE] ET AL) 6 July 2004 (2004-07-06) figure 3	22-24,26

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 July 2014	18/07/2014

Name and mailing address of the ISA/	Authorized officer
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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

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