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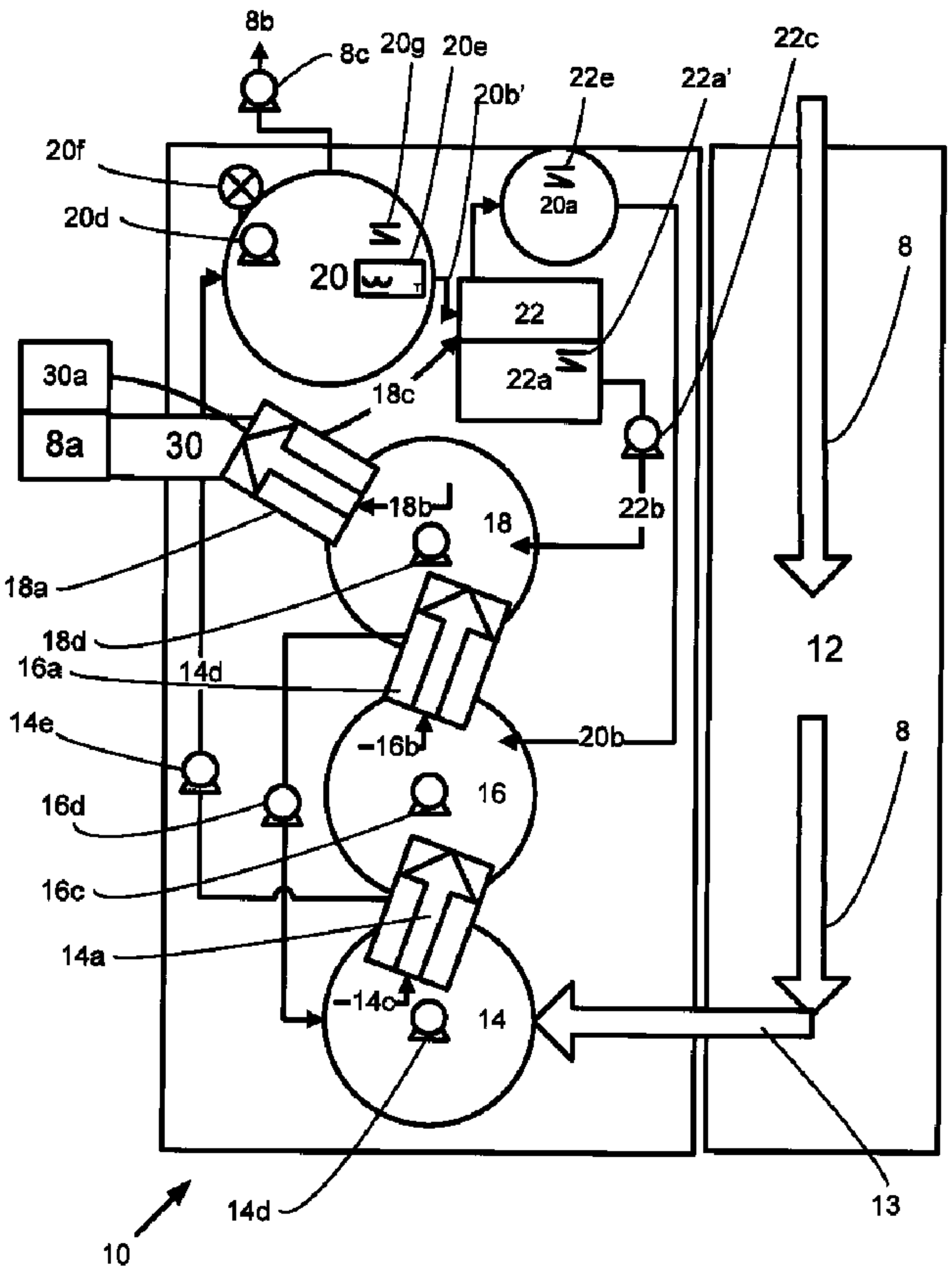


(57) Abrégé/Abstract:
This application describes a method and apparatus for cleaning drill cuttings from a wellbore. Specifically, the apparatus includes an effective system for handling and washing drill cuttings in a modular system adapted for use at a well site. The system successively washes hydrocarbon contaminated drill cuttings in organic solvent and water to remove and recover the hydrocarbon contaminates enabling disposal of clean drill cuttings.

ABSTRACT

This application describes a method and apparatus for cleaning drill cuttings from a wellbore. Specifically, the apparatus includes an effective system for handling and washing drill cuttings in a modular system adapted for use at a well site. The system successively washes hydrocarbon contaminated drill cuttings in organic solvent and water to remove and recover the hydrocarbon contaminates enabling disposal of clean drill cuttings.

METHOD AND APPARATUS FOR CLEANING DRILL CUTTINGS

FIELD OF THE INVENTION

Methods and apparatus for cleaning drill cuttings from a wellbore are described. Specifically, the apparatus includes an effective system for handling and washing drill cuttings in a modular system adapted for use at a well site. The system successively washes hydrocarbon contaminated drill cuttings in organic solvent and water to remove and recover the hydrocarbon contaminates enabling disposal of clean drill cuttings. Methods of washing hydrocarbon contaminated drill cuttings are also described.

BACKGROUND OF THE INVENTION

In the process of drilling oil wells, segments of rock, clay or the like (hereafter drill cuttings or drilling waste) are created by the drilling process and are carried to the surface by drilling fluid circulating in the well. In addition to carrying drilling waste to the surface, the drilling fluid serves other purposes including strengthening the walls of the wellbore, preventing contamination of the well and damage to the various formations, protecting metal parts from corrosion, providing lubrication to the drilling string as well as cooling and lubricating the drill bit during drilling.

The drilling fluids used in drilling a well are often a hydrocarbon based slurry commonly referred to as an “oil mud”. An oil mud is generally comprised of a high proportion of oil based fluids together with other additives that are designed to impart specific properties to the drilling fluid. Drilling fluids are generally expensive fluids that constitute a significant expense of a drilling program. Moreover, as drill cuttings are carried to the surface, they will absorb hydrocarbons or will otherwise become coated with hydrocarbons contained in the oil mud and from hydrocarbons released from various formations. As a result of this contamination, the drilling waste is unfit for simple disposal at the surface. Accordingly, at surface, drill cuttings and the drilling fluid will be subjected to various separation techniques (most commonly a shaker) in order to recover as much drilling fluid as possible for re-use in the well and to clean the drill cuttings for disposal.

In addition, hydrocarbon contaminated drill cuttings must be treated and/or cleaned before disposal in order to mitigate environmental damage and otherwise comply with government regulations.

However, most drill cutting/drilling fluid separation technologies only provide a preliminary separation of drill cuttings and drill fluid with the end result being that substantial amounts of hydrocarbons (up to approximately 15 wt% of the mass of the drill cuttings) from the drilling fluid and the formations remain coated on the drill cuttings after rudimentary surface separation. As noted above, as both drilling fluid and other hydrocarbons are valuable and government regulations require either cleaning of drill cuttings or special containment at a disposal site, there has been a need for improved techniques to recover drilling fluid and hydrocarbons from drill cuttings and provide clean drill cuttings that can be readily disposed of and to recover the oil contaminants. While cleaning drill cuttings has been accomplished by various techniques in the past, it is important that the costs of cleaning contaminated drill cuttings are reasonable and/or are improved over past techniques. More specifically, there has been a need for both improved systems and methods enabling the efficient cleaning of drill cuttings under field conditions.

A review of the prior art reveals that various technologies have been described in the past. For example, Canadian Patent 2,317,858 and United States Patent 6,550,552 to Pappa et al. discloses a washing process in which drill cuttings contaminated with an oil-based drilling fluid are successively washed using ethyl acetate or hexane. United States Patent 5,755,892 to Herold et al. discloses washing drill cutting with ecologically compatible, biologically degradable oil. United States Patent 4,645,608 to Rayborn discloses separating oil contaminated cuttings from a drilling mud, contacting the cutting with a detergent solution to remove the oil from the cuttings and returning the oil and detergent solution to the drilling mud. United States Patent 4,942,929 to Malachosky et al. discloses removing drill cuttings from a well and sequentially passing cuttings through a shale shaker, washing with water and disposing of the cuttings. United States Patent 6,846,420 to Reddy et al. discloses introducing drill cuttings into a separating zone, adding an aqueous acidic solution containing a polymer substituted with an amino group and a halogenating agent such as sodium hypochlorite ("bleach") and United

States Patent 5,199,997 to Stowe discloses a first inclined tub containing a heated stripper solution, a second inclined tub containing a hot rinse liquid and a third inclined tub containing cold rinse water for removing oil from drill cuttings.

SUMMARY OF THE INVENTION

In accordance with the invention, there is provided a system for cleaning hydrocarbon contaminated drill cuttings comprising: a contaminated drill cuttings delivery system for delivering contaminated drill cuttings; a first wash tank and separation system operatively connected to the contaminated drill cuttings delivery system for washing contaminated drill cuttings in a partially used organic solvent and thereafter separating partially cleaned drill cuttings and used organic solvent; a second wash tank and separation system operatively connected to the first wash tank and separation system for washing partially cleaned drill cuttings in a clean organic solvent and thereafter separating cleaned drill cuttings and partially used organic solvent; a third wash tank and separation system operatively connected to the second wash tank and separation system for washing the cleaned drill cuttings in water and thereafter separating water-cleaned drill cuttings and water; and, a solvent distillation system operatively connected to the first wash tank and separation system for distilling used organic solvent for recovery of clean organic solvent for the second wash tank and separation system and recovery of hydrocarbon contaminants.

In a further embodiment, the system includes a heat exchanger operatively connected to the solvent distillation system for condensing solvent vapor with water from the third wash and separation system.

In a preferred embodiment, the organic solvent is n-butyl alcohol (NBA). The ratio of organic solvent to drill cuttings is preferably 0.5-2.0:1 (by volume) and more preferably 1:1.

In yet another embodiment, the first, second and third wash tanks and separation systems include a solvent distribution system having a plurality of distributor arms for providing countercurrent and radial flow of solvent or water over falling drill cuttings.

In yet another embodiment, at least one of the first and second wash tanks is sealed from the atmosphere.

In another embodiment, the first, second and third wash tanks and solvent distillation system are operatively contained with a modular enclosure.

In another aspect of the invention, there is provided a method for cleaning hydrocarbon contaminated drill cuttings comprising the steps of:

washing contaminated drill cuttings in a partially used organic solvent and thereafter separating partially cleaned drill cuttings and used organic solvent;

washing partially cleaned drill cuttings in a clean organic solvent and thereafter separating cleaned drill cuttings and partially used organic solvent;

washing the cleaned drill cuttings in water and thereafter separating water cleaned drill cuttings and water; and,

distilling used organic solvent from step i) for recovery of clean organic solvent for step ii) and hydrocarbon contaminants.

In another embodiment, the method further comprises the step of condensing organic solvent vapor from step iv) using water from step iii).

BRIEF DESCRIPTION OF THE FIGURES

The invention is described with reference to the accompanying figures in which:

Figure 1A is a schematic side view of a storage/delivery system in accordance with one embodiment of the invention;

Figure 1B is a schematic plan view of a storage/delivery system in accordance with one embodiment of the invention;

Figure 2 is a schematic plan view of a drill cuttings cleaning apparatus in accordance with one embodiment of the invention;

Figure 3A is a schematic side view a drill cuttings wash tank in accordance with one embodiment of the invention;

Figure 3B is a schematic plan view of a wash tank showing distributor arms in accordance with one embodiment of the invention; and,

Figure 4 is a schematic view of a modular system in accordance with one embodiment of the invention.

DETAILED DESCRIPTION

Overview

With reference to the figures a system 10 and method for cleaning drill cuttings from a wellbore during oilfield drilling operations is described. The system 10 generally includes a contaminated drill cutting storage/delivery system 12, a first wash tank 14 and first shaker 14a, a second wash tank 16 and second shaker 16a, a third wash tank 18 and third shaker 18a, a solvent distillation system 20, and a heat exchange system 22. Contaminated drill cuttings 8 are moved through the system as shown by the arrows in Figures 2 and 4 to create clean cuttings 8a and recovered drilling fluid/oil 8b.

Storage/Delivery System 12

Drill cuttings 8 contaminated with drilling fluid and/or hydrocarbons from a wellbore are introduced into a storage/delivery system 12 after the drill cuttings have been removed from a standard shaker (not shown) at a drilling site. Typical drill contaminated drill cuttings will include a full range of particle sizes ranging from fines (typically 20 to 100 microns in size) to 1-2 cm rock chips. Hydrocarbon/drilling fluid contamination of the drill cuttings may be in the range of 15 wt% of the total mass of the drill cuttings. As shown in Figure 1A, the storage/delivery system will preferably be a hopper bin having inwardly sloped outer walls 12a to allow drill cuttings to fall towards the center of the hopper bin. A floor having a screen 12b will allow loosely bound drilling fluid/oil contaminants on the drill cuttings to flow via gravity to an under-floor collection system 12d for recovery 12c. Preferably, the storage/delivery system will include an appropriate solids transfer systems such as an infloor chain drag 12d to move drill cuttings along the floor of the hopper bin for removal. Cuttings may be introduced to the hopper bin by an appropriate solids transfer system 12f such as a chain drag or other suitable delivery system.

First Wash Tank

As shown in Figure 2, contaminated drill cuttings are moved from the storage/delivery bin 12 by an auger 13 to a first wash tank 14 containing an organic solvent. The drill cuttings are introduced to the top of the first wash tank wherein the cuttings 8 are distributed and allowed to drop through the tank through the solvent thereby creating a slurry as best shown in Figure 3A. Solvent is circulated within the tank by recirculation pump 14d where solvent is pumped to the bottom of the tank and through nozzles allowing the solvent to then flow upwardly and counter-current to the falling drill cuttings. In a preferred embodiment, as shown in Figure 3B, solvent is jetted through one or more distributor arms 14b in a radial direction (relative to the distributor arms) and a circumferential direction (relative to the tank wall) so as to provide both agitation and a centrifugal force to the slurry. The combined radial and circumferential movement of the slurry will generally promote depositing heavier particles towards the outer edges of the tank which will generally provide free solvent towards the center of the tank for recirculation of the free solvent by recirculation pump 14d.

The average residence time of cuttings in the first wash tank will be typically 20-30 minutes. A solvent/solid volume ratio of 0.5 to 2.0 is used (more preferably 1:1).

First Shaker 14a

Cuttings, upon reaching the bottom of the tank 14 are pumped (together with solvent) to a first shaker 14a operably connected between the first wash tank 14 and a second wash tank 16 by a solids pump 14c.

The first shaker separates partially cleaned drill cuttings from the solvent. The partially cleaned drill cuttings will fall into the top of the second wash tank 16 containing clean solvent. Separated solvent 14d from the first shaker 14a will be collected and returned to a solvent distillation unit 20. The system may also include a holding tank (not shown) for storing solvent prior to introduction into the solvent distillation unit 20.

Second Wash Tank 16

The second wash tank 16 provides further cleaning of the partially cleaned drill cuttings. Preferably, clean solvent 20b (explained in greater detail below) from the solvent distillation unit 20 is introduced into the second wash tank 16 in order that the partially cleaned drill cuttings from the first wash tank are subjected to further solvent cleaning with an uncontaminated solvent so as to improve the effectiveness of drill cutting cleaning in the second wash tank 16. As with the first wash tank 14, drill cuttings are introduced to the top of the second wash tank wherein the cuttings are distributed and allowed to drop through the second wash tank through the solvent. Clean solvent is simultaneously introduced to the bottom of the tank and flows upwardly and counter-current to the falling drill cuttings by recirculation pump 16c. Agitation is provided as described above. Cuttings are pumped to second shaker 16a by solids pump 16b.

The average residence time of cuttings in the first wash tank will be typically 20-30 minutes with a preferred solvent/solid volume ratio of 0.5 to 2 (preferably 1:1).

Second Shaker 16b

Cleaned cuttings, upon reaching the bottom of the second wash tank 16 are pumped (together with solvent) to a second shaker 16a operably connected between the second wash tank 16 and a third wash tank 18 by solids pump 16b.

The second shaker 16a separates cleaned drill cuttings from the solvent. The cleaned drill cuttings fall into the top of the third wash tank 18 containing clean water. Separated solvent 16c from the second shaker is collected and returned to the first wash tank 14.

Third Wash Tank 18

The third wash tank 18 provides a final cleaning of the drill cuttings in water. Water 22b from the heat exchanger 22 is introduced into the third wash tank 18 in order that the cleaned drill cuttings from the second wash tank are subjected to a final water rinse. The water rinse removes residual solvent and oil, as well as various salts and dissolved minerals that are generally found on the drill cuttings when they are recovered from the well. As with the first and second wash tanks, drill cuttings are introduced to the top of the third wash tank 18 wherein the cuttings are distributed and allowed to drop through the third wash tank 18 through the water. Water is simultaneously introduced to the bottom of the third wash tank and flows upwardly and counter-current to the falling drill cuttings by recirculation pump 18d. Agitation is provided as described above. The average residence time of cuttings in the third wash tank will be typically 20-30 minutes with a preferred water/solid volume ratio of 0.5 to 2 (preferably 1:1).

Third Shaker 18a

Cleaned cuttings, upon reaching the bottom of the third wash tank 18 are pumped (together with water) to a third shaker 18a operably connected between the third wash tank and a cleaned cuttings handling system by a solids pump 18b.

The third shaker 18a separates cleaned drill cuttings from the water. The cleaned drill cuttings fall off the third shaker 18a where they are removed by a cleaned cuttings handling system 30 for removal from the system as clean cuttings 8a. Separated water 18c from the third shaker 18a is collected and returned to the heat exchanger 22.

Cuttings Removal System 30

In one embodiment, clean cuttings are removed from the system and specifically from the third shaker by an auger 30 to a storage/disposal area. A blower 30a may be incorporated to assist in the movement of cuttings through the auger. In other embodiments, a conveyor belt or other solids transport system known to those skilled in the art may be utilized.

Solvent Distillation Unit 20 and Heat Exchanger 22

The solvent distillation unit 20 receives contaminated solvent 14d from the first wash tank 14 from shaker 14a. The contaminated solvent 14d is introduced into the side of the solvent distillation unit 20 where it is heated under vacuum to vaporize the solvent. Recovered drilling fluid/oil 8b is removed from the bottom of the unit for recovery and re-use. Solvent vapor 20b' is condensed in heat exchanger 22 with cold water. Condensed vapor 20b is then pumped to the second wash tank 16 by vacuum pump 20a. Heat exchanger 22 may include storage tanks 22a for bulk water storage as may be required based on the heat exchanger requirements. In addition, depending on the size of the distillation unit, additional water cooling may be required and necessitate the inclusion of additional heat exchangers to provide sufficient cooling to the distillation unit 20. The distillation unit will include appropriate heaters as known to those skilled in the art.

Solvents

The preferred solvent for use with the system is n-butyl alcohol. n-butyl alcohol is a preferred solvent because of its relative insolubility in water (9% soluble in water) and its effectiveness in dissolving drill cuttings contaminants. Low solubility is important to minimize contamination of the water. While n-butyl alcohol has a higher boiling temperature compared to other solvents such as ethyl acetate which may increase energy consumption due to higher distillation temperatures, n-butyl alcohol has a higher flash point which contributes to improved material handling and safety at a worksite. However, n-butyl alcohol was found to provide superior cleaning of drill cuttings using the same cleaning protocol as compared to other solvents which significantly improves the overall cost effectiveness of the subject system and method as will be described below.

In one embodiment, each of the wash tanks is sealed to prevent vapors from escaping and thereby further improve the safety of the system. The system may also utilize a purge gas such as nitrogen.

In a further embodiment, each of the wash tanks may utilize different solvents having different boiling points and oil-cleaning properties. In this case, the distillation unit may utilize a single column and/or multiple columns to effect solvent separation.

Water

Over time, water in the system will become contaminated with fines and small concentrations of solvent which that will require treatment or disposal. In a preferred embodiment, the distillation system 20 is utilized to clean the water used to rinse the cuttings. That is, when time permits, for example when drilling may be progressing slowly, the distillation system can be used to remove the contaminants out of the water by distillation, thereby returning the water to a fully reusable state. Further, the contaminants left behind in the distillation system are often naturally occurring/added products used in the drilling process which can then be returned to the oil mud and re-used in the drilling process. Alternatively, a separate water distillation system (not shown) may be configured to the system to enable separate water cleaning.

Energy Consumption

Importantly, the subject system provides improved energy consumption efficiency over past systems particularly with respect to energy costs for distillation. In particular, by using clean solvent for polishing partially cleaned drill cuttings in the second wash tank and returning that solvent to the first wash tank, the overall efficiency of solvent consumption is improved as compared to a process in which solvent is distilled after each wash. This is of particular advantage when drill cuttings are being cleaned at a drill site which would normally be off the power grid and would, therefore require diesel fuel to provide all energy for the process. The transportation and material costs of diesel fuel are reduced if less overall energy is required in the process.

Furthermore, the use of n-butyl alcohol as a solvent is more effective in cleaning drill cuttings as compared to other solvents such as ethyl acetate and hexane. As a result, an equivalent or greater degree of decontamination can be achieved utilizing a smaller volume of solvent. Thus, in a closed or partially closed system, the energy costs for distillation are reduced.

System Sensors and Control

In a preferred embodiment, the system is automated such that a single operator can monitor and adjust the equipment as required during a typical drill cutting cleaning job and to maintain safe operation of the system.

Sensors and pumps are configured to a single control station 44 (Figure 4) to enable both automatic and manual control of the movement of fluids and solids through the system. By way of example and as shown in Figure 2, the system will include pumps 14e and 16c for pumping fluids recovered from the shakers 14a and 16a respectively to the associated downstream vessel. Transfer of fluids may also simply be by gravity feed where appropriate. In addition, pump 22c is used to return water to wash tanks18 and pump 8c is used to remove recovered oil from the system. The distillation system may include a circulating pump 20d as well as appropriate temperature 20e and pressure sensors 20f. Level sensors 20g, 22e and 22a' provide fluid level information to assist in the control of the pumps.

Examples

Representative examples of the degree of decontamination of various hydrocarbons from drill cuttings are shown in Table 1. More specifically, Table 1 shows the degree of decontamination of four samples of drill cuttings having an initial hydrocarbon contamination of approximately 100,000-150,000 ppm.

In the table, samples 1-4 were subjected to a cleaning process using n-butyl alcohol (2 solvent washes) and water (polishing) where the ratio of n-butyl alcohol:drill cuttings was 1:1 (by volume). The first solvent wash was a "dirty" wash and the second solvent wash was a "clean" solvent wash as described above. The residence time for each wash was 30 minutes. The untreated samples of drill cuttings, leached (dry) and saturated (wet) were collected from the top and bottom of the storage system respectively and were characterized by the relative degree of "wetness". That is, the leached (dry) drill cuttings were characterized by having allowed loose oil contaminants to have drained off the cuttings whereas the saturated (wet) cuttings were fully saturated with oil contaminants that had drained to the bottom of the storage system. As shown, as compared to the untreated samples, each treated sample was effectively stripped of greater than 98% of total oil contaminants thus showing the effectiveness of n-butyl alcohol as a solvent.

Table 1-Decontamination of Representative Samples

Parameter	Units	RDL	Sample 1	Sample 2	Sample 3	Sample 4	Leached Dry (untreated)	Saturated Wet (untreated)
C6 - C10 (F1)	mg/kg	10	<10	20	20	10	100	130
C6 - C10 (F1 minus BTEX)	mg/kg	10	<10	10	10	10	90	120
C10 - C16 (F2)	mg/kg	10	288	447	382	371	34800	45900
C16 - C34 (F3)	mg/kg	10	594	874	748	1040	56400	73600
C34 - C50 (F4)	mg/kg	10	<10	11	13	<10	201	310
Totals:			912	1362	1173	1441	91591	120060

BTEX -Benzene, Toluene, Ethylbenzene & Xylenes
RDL- Reported Detection Limit

In addition, the same samples were subjected to standardized Microtox™ (AZUR Environmental, Carlsbad, California) analysis to determine the relative degree of toxicity of the treated samples in accordance with standard EC50 testing protocols. Following an initial test using the basic EC50 testing protocol, those samples that failed the initial test were treated with charcoal and re-tested in accordance with standard Microtox™ testing procedures. As shown in Table 2, samples 3 and 4 passed the original Microtox™ test wherein for each sample, greater than 75% of the testing organism survived upon exposure to the treated samples. In addition, samples 1 and 2 passed the Microtox™ after treatment with charcoal thus showing the overall effectiveness of the process in meeting the Microtox™ treatment standards.

Table 2-Microtox™ Analysis

Parameter	Unit	Sample 1	Sample 2	Sample 3	Sample 4
Microtox™ original		Failed	Failed	Passed	Passed
Microtox™ - EC50 (15 minutes)	%	38.32	64.25	75.66	>81.90
Microtox™ (charcoal)		Passed	Passed	N/A	N/A
Microtox™ - EC50 Charcoal (15 minutes)	%	>81.90	>81.90	N/A	N/A

In addition, representative drill cutting samples were tested with different solvents, solvent ratios and number of cleaning steps (solvent washes).

As shown in Table 3, the results of treatment with n-butyl alcohol (1 part drill cuttings to 1 part solvent) in a single solvent wash (Sample 1), n-butyl alcohol (1 part drill cuttings to 2 parts solvent) in a single solvent wash (Sample 2) using clean solvent are compared against hexane (1 part drill cuttings to 1 part solvent) with 2 clean solvent washes (Sample 3), and ethyl acetate (1 part drill cuttings to 1 part solvent) with 2 clean solvent washes (Sample 4). As shown, and as compared to the results of Table 1, 2 solvent washes in hexane provided a superior result over a single solvent wash with NBA in clean solvent (see samples 3 and 1). In addition, increasing the solvent ratio provided superior cleaning in a single wash (see samples 1 and 2). However, a single clean solvent wash in NBA was superior to 2 clean solvent washes in ethyl acetate (see samples 4, 2 and 1). As a result, it is clear that the use of NBA provided superior cleaning capabilities with approximately half the volume of solvent. As a result, in a closed or partially closed system in which solvent is distilled and recovered, the approximate energy cost in using NBA is roughly 50% of the energy cost of hexane or ethyl acetate while providing superior cleaning. That is, 2 washes with NBA with clean and dirty solvent as shown in Table 1 will result in approximately 1200 mg/kg of total remaining hydrocarbon contamination. However, as the same volume of solvent is used twice, it is only distilled once. In comparison, as shown in Table 3, two washes in clean hexane or ethyl acetate did produce the same degree of hydrocarbon removal (ie. 3239 and 5559 mg/kg respectively). Thus, for the same volume of solvent, in the hexane and ethyl acetate systems, the solvent would have to be distilled twice. As a result, the energy costs for NBA would be approximately 50% that of a hexane or ethyl acetate system.

Table 3- Comparison of Solvents, Solvent Ratios and Solvent Washes

Parameter	Units	RDL	Sample 1 (NBA)	Sample 2 (NBA)	Sample 3 (Hexane)	Sample 4 (Ethyl Acetate)	Leached Dry (untreated)	Saturated Wet (untreated)
C6 - C10 (F1)	mg/kg	10	10	10	20	18	100	130
C6 - C10 (F1 minus BTEX)	mg/kg	10	10	<10	20	17	90	120
C10 - C16 (F2)	mg/kg	10	1210	558	697	1600	34800	45900
C16 - C34 (F3)	mg/kg	10	3380	1600	2320	3900	56400	73600
C34 - C50 (F4)	mg/kg	10	33	25	182	23	201	310
Total:			4643	2203	3239	5558	91591	120060

Modular Skid Design

In a preferred embodiment, the system 10 is assembled in modules so as to facilitate transportation to and from a well site and assembly and operation at the well site.

In a typical drilling operation, the drill cutting cleaning equipment in accordance with the invention will be required at a drill site for about 30 days and may require movement between various local sites during that time.

As shown in Figure 4, a typical modular layout is shown together with the flow of drill cuttings through the system. The modules, in accordance with the invention, include a contaminated drill cutting storage/delivery module 12, wash module 40, cleaned cuttings module 42, control module 44, power module 46 and contaminated cuttings container 48. Each module is preferably sized to facilitate loading and transportation on typical flat-bed trucking trailers.

As shown in Figure 4, the power module provides power to each of the contaminated drill cutting storage/delivery module 12, wash module 40, cleaned cuttings module 42 and control module 44. Input/output to and from the control module is provided to the contaminated drill cutting storage/delivery module 12, wash module 40, cleaned cuttings module 42 and power module 46.

It is understood that the various alterations may be made to the invention as herein described as understood by those skilled in the art.

CLAIMS

1) A system for cleaning hydrocarbon contaminated drill cuttings comprising:

a contaminated drill cuttings delivery system for delivering contaminated drill cuttings;

a first wash tank and separation system operatively connected to the contaminated drill cuttings delivery system for washing contaminated drill cuttings in a partially used organic solvent and thereafter separating partially cleaned drill cuttings and used organic solvent;

a second wash tank and separation system operatively connected to the first wash tank and separation system for washing partially cleaned drill cuttings in a clean organic solvent and thereafter separating cleaned drill cuttings and partially used organic solvent;

a third wash tank and separation system operatively connected to the second wash tank and separation system for washing the cleaned drill cuttings in water and thereafter separating water-cleaned drill cuttings and water;

a solvent distillation system operatively connected to the first wash tank and separation system for distilling used organic solvent for recovery of clean organic solvent for the second wash tank and separation system and recovery of hydrocarbon contaminants.

2) A system as in claim 1 further comprising a heat exchanger operatively connected to the solvent distillation system for condensing solvent vapor with water from the third wash and separation system.

3) A system as in any one of claims 1-2 wherein the organic solvent is n-butyl alcohol.

4) A system as in any one of claims 1-3 wherein the first, second and third wash tanks and separation systems include a solvent distribution system having a plurality of distributor arms for providing countercurrent and radial flow of solvent or water over falling drill cuttings.

5) A system as in any one of claims 1-4 wherein the ratio of organic solvent to drill cuttings is 0.5-2.0:1 (by volume).

6) A system as in claim 5 wherein the ratio of organic solvent to drill cuttings is 1:1 (by volume)

7) A system as in any one of claims 1-6 wherein at least one of the first and second wash tanks is sealed from the atmosphere.
8) A system as in any one of claims 1-7 wherein solvent and drill cuttings are separated by a shaker.
9) A system as in any one of claims 1-8 wherein the first, second and third wash tanks and solvent distillation system are operatively contained within a wash module.
10) A system as in claim 9 further comprising a contaminated drill cutting storage/delivery module for storing and delivering contaminated drill cuttings to the wash module.
11) A system as in claim 10 further comprising a cleaned cuttings module for storing cleaned cuttings.
12) A system as in claim 11 further comprising a control module and a power module operatively connected to the contaminated drill cutting storage/delivery module and wash module.
13) A method for cleaning hydrocarbon contaminated drill cuttings with an organic solvent comprising the steps of:
    i) washing contaminated drill cuttings in a partially used organic solvent and thereafter separating partially cleaned drill cuttings and used organic solvent;
    ii) washing partially cleaned drill cuttings in a clean organic solvent and thereafter separating cleaned drill cuttings and partially used organic solvent;
    iii) washing the cleaned drill cuttings in water and thereafter separating water cleaned drill cuttings and water;
    iv) distilling used organic solvent from step i) for recovery of clean organic solvent for step ii) and hydrocarbon contaminants.
14) A method as in claim 13 further comprising the step of condensing organic solvent vapor from step iv) using water from step iii).
15) A method as in any one of claims 13-14 wherein the ratio of organic solvent to drill cuttings is 0.5-2.0:1 (by volume).
16) A method as in claim 15 wherein the ratio of organic solvent to drill cuttings is 1:1 (by volume).

17)A method as in any one of claims 13-16 wherein the residence time of partially cleaned, cleaned and water cleaned drill cuttings in each of steps i) to iii) is controlled such that the level of decontamination of the water cleaned drill cuttings relative to the hydrocarbon contaminated drill cuttings is greater than 95%.

18)A method as in claim 17 wherein the level of decontamination of the water cleaned drill cuttings relative to the hydrocarbon contaminated drill cuttings is greater than 98%.

19)A method as in any one of claims 13-18 wherein each of the partially used organic solvent and clean organic solvent are maintained in a closed system and recycled by re-use by step iv).

20) A method as in any one of claims 13-19 where the organic solvent is n-butyl alcohol.

FIGURE 1A

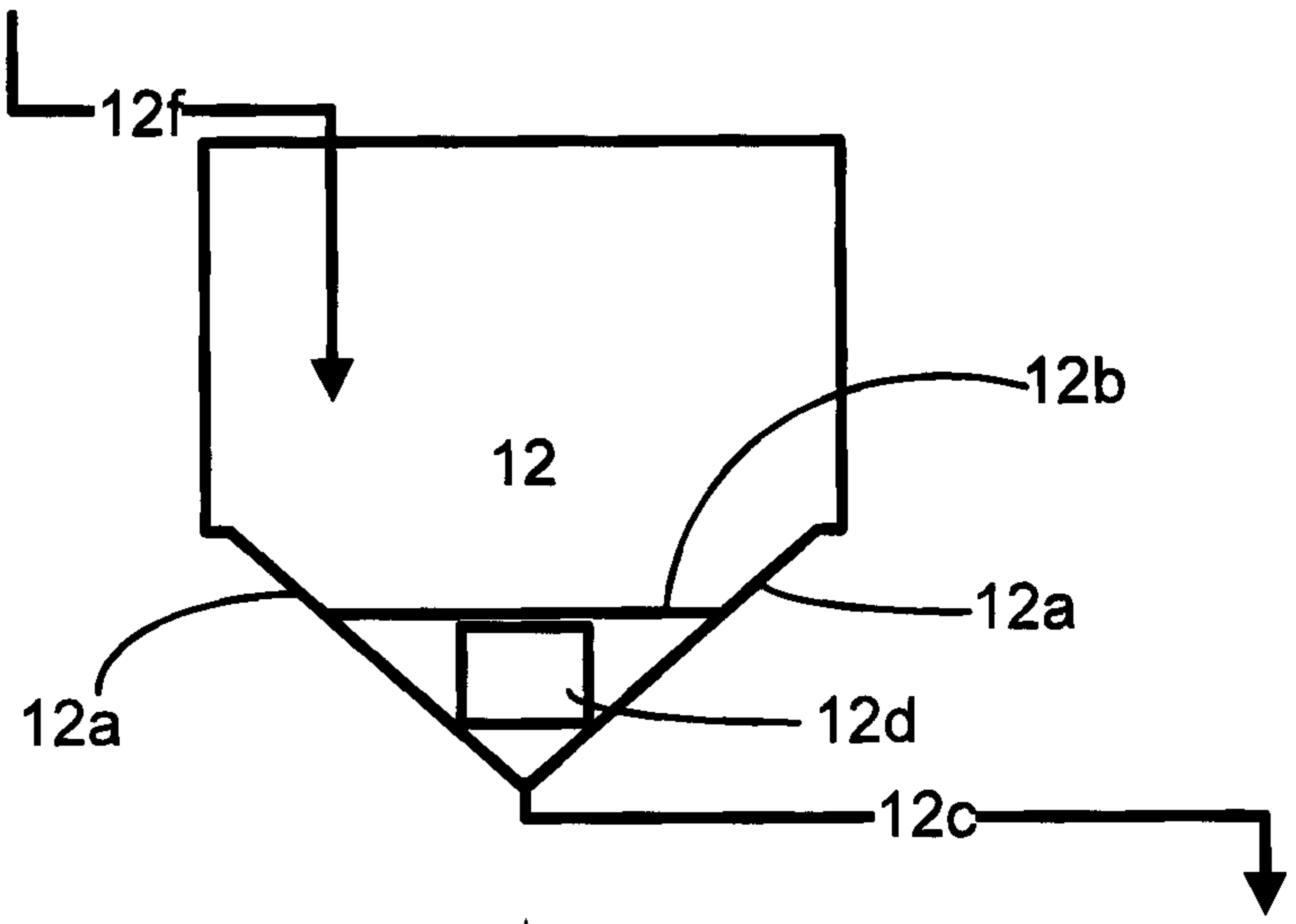
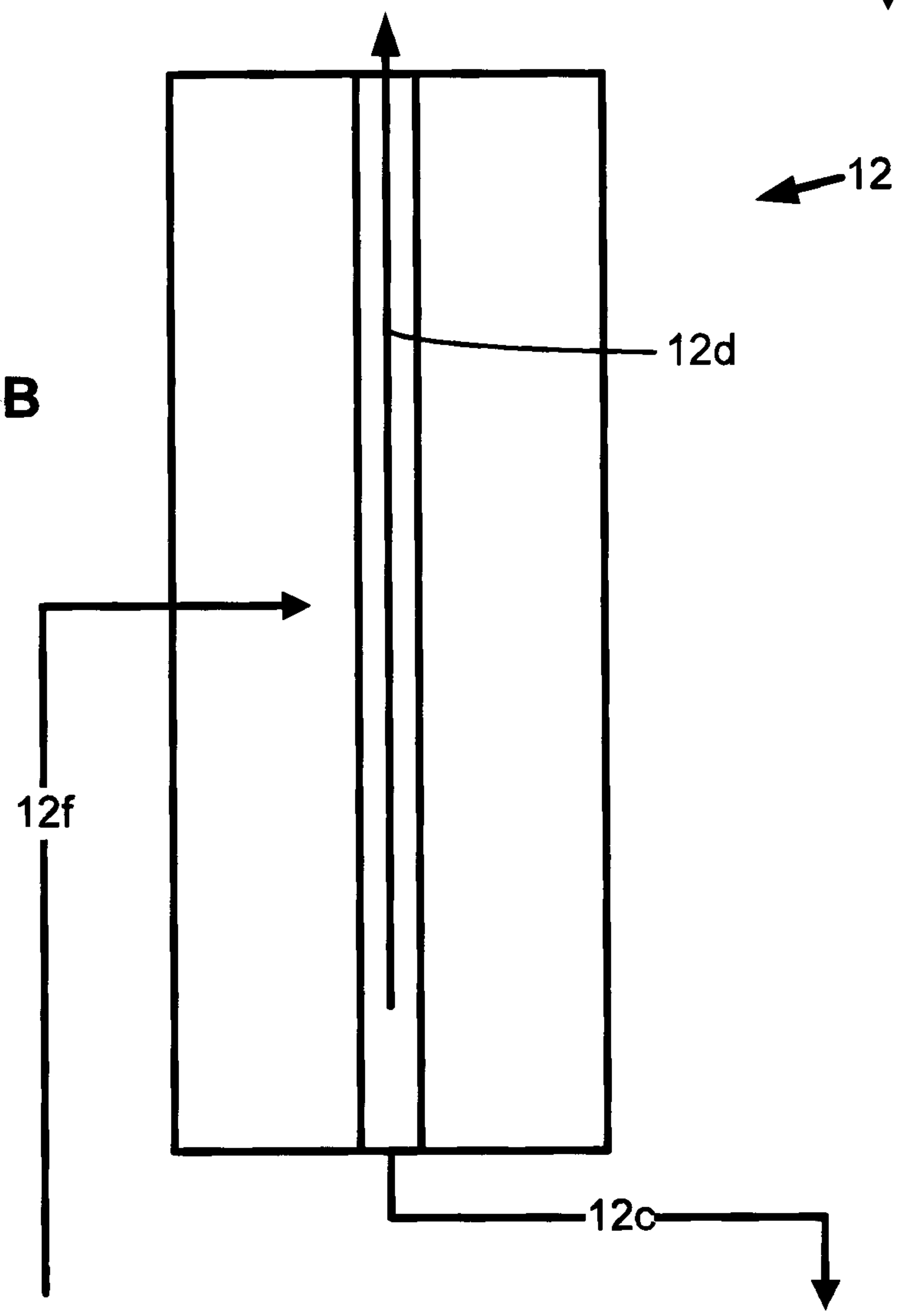


FIGURE 1B



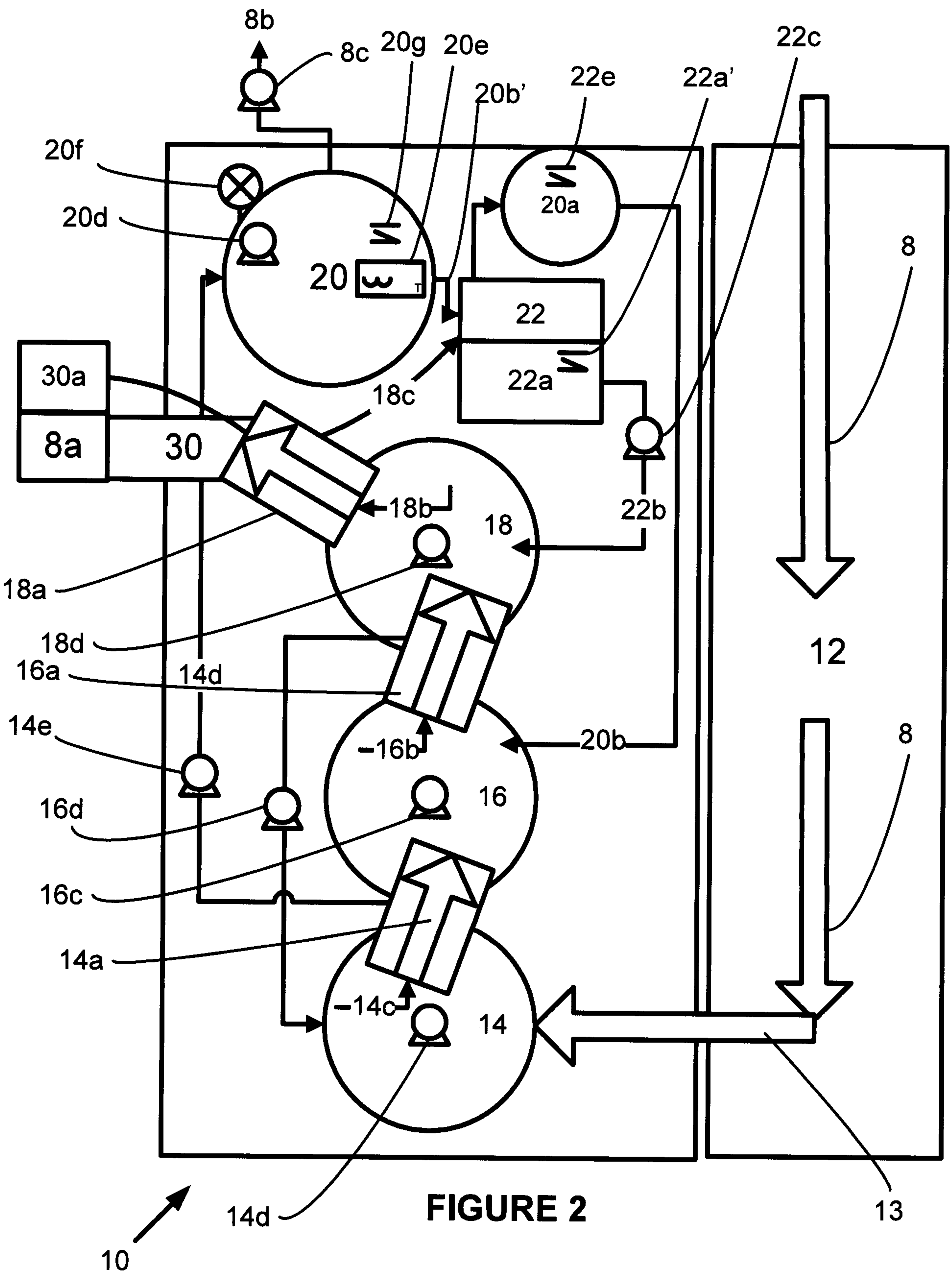

8b
8c
20g
20e
20b'
22e
22a'
22c
20f
20d
20
20a
22
22a
30a
8a
30
18c
18b
18
22b
18a
18d
16a
14d
16b
20b
16
14e
16d
16c
14a
14c
14
12
8
8
13
14d
10

FIGURE 2

FIGURE 3A

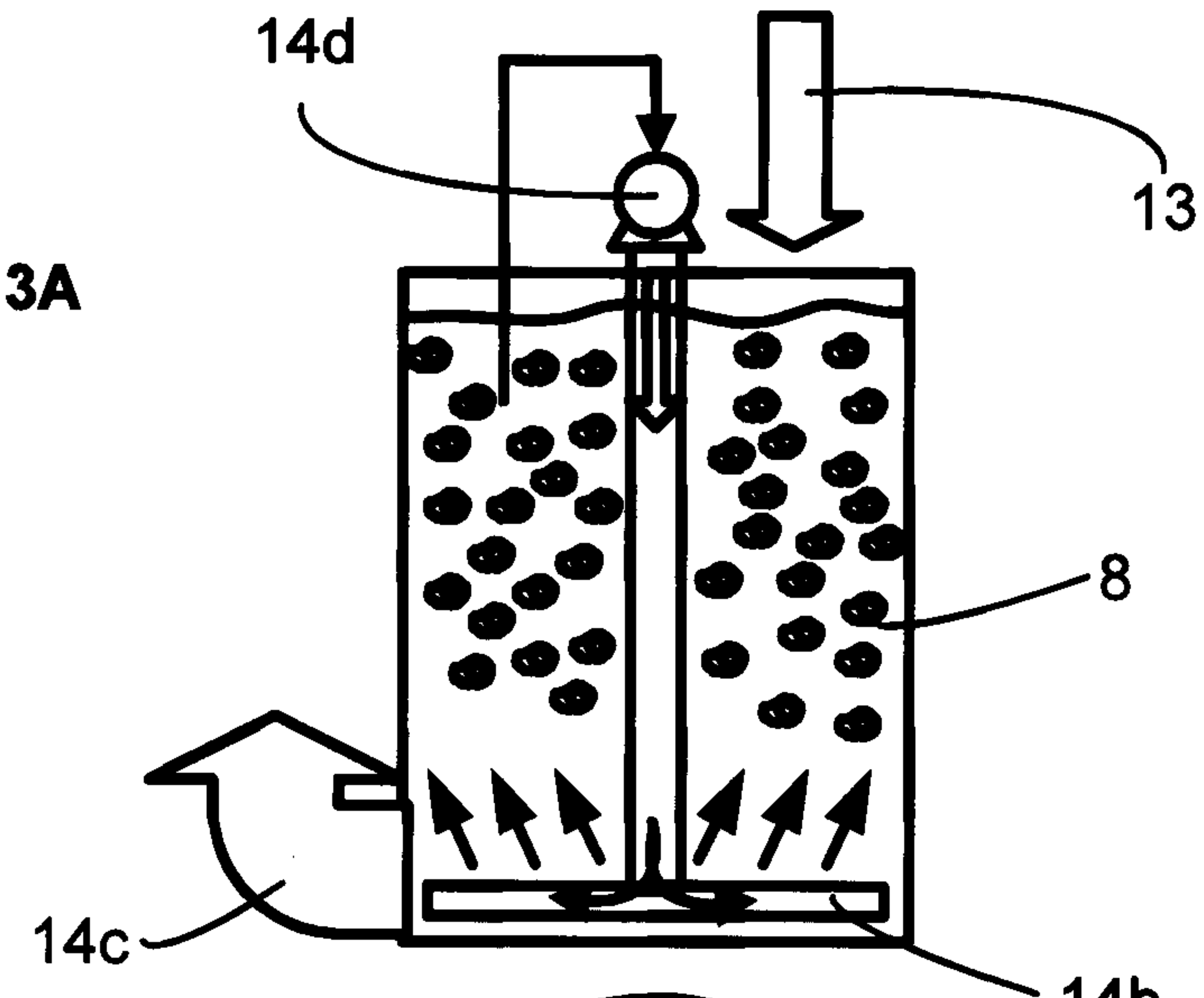
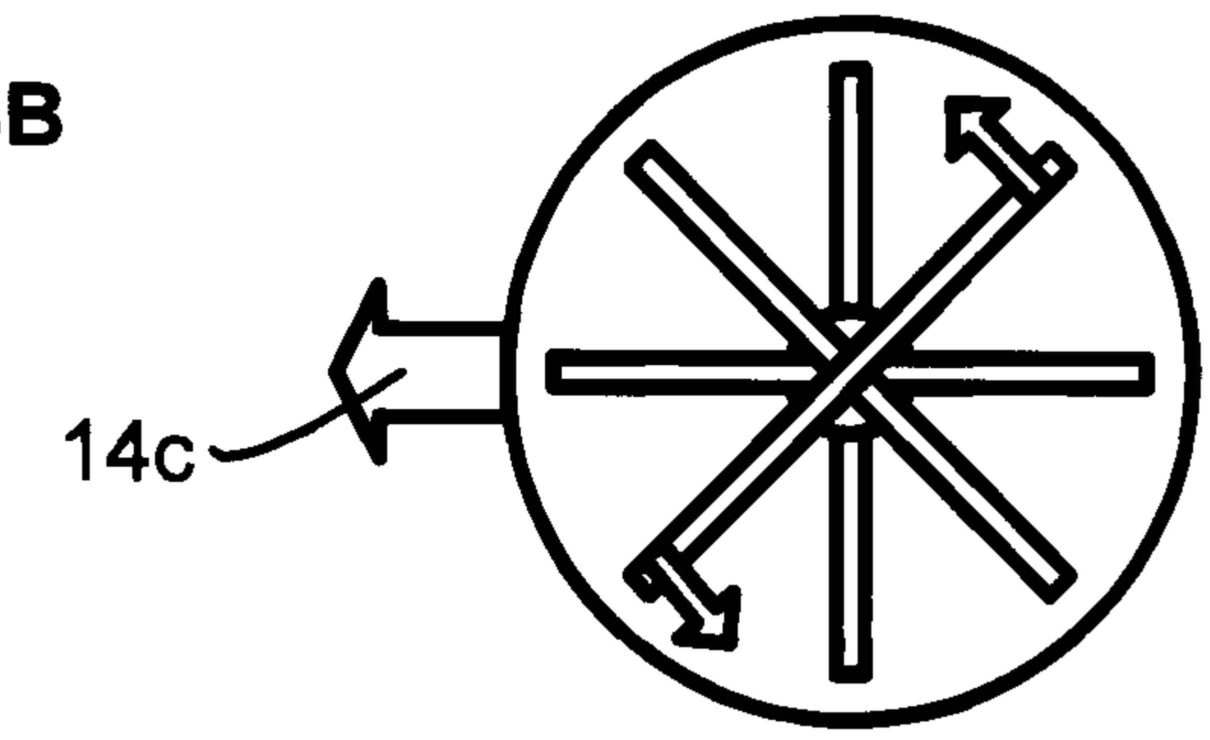


FIGURE 3B



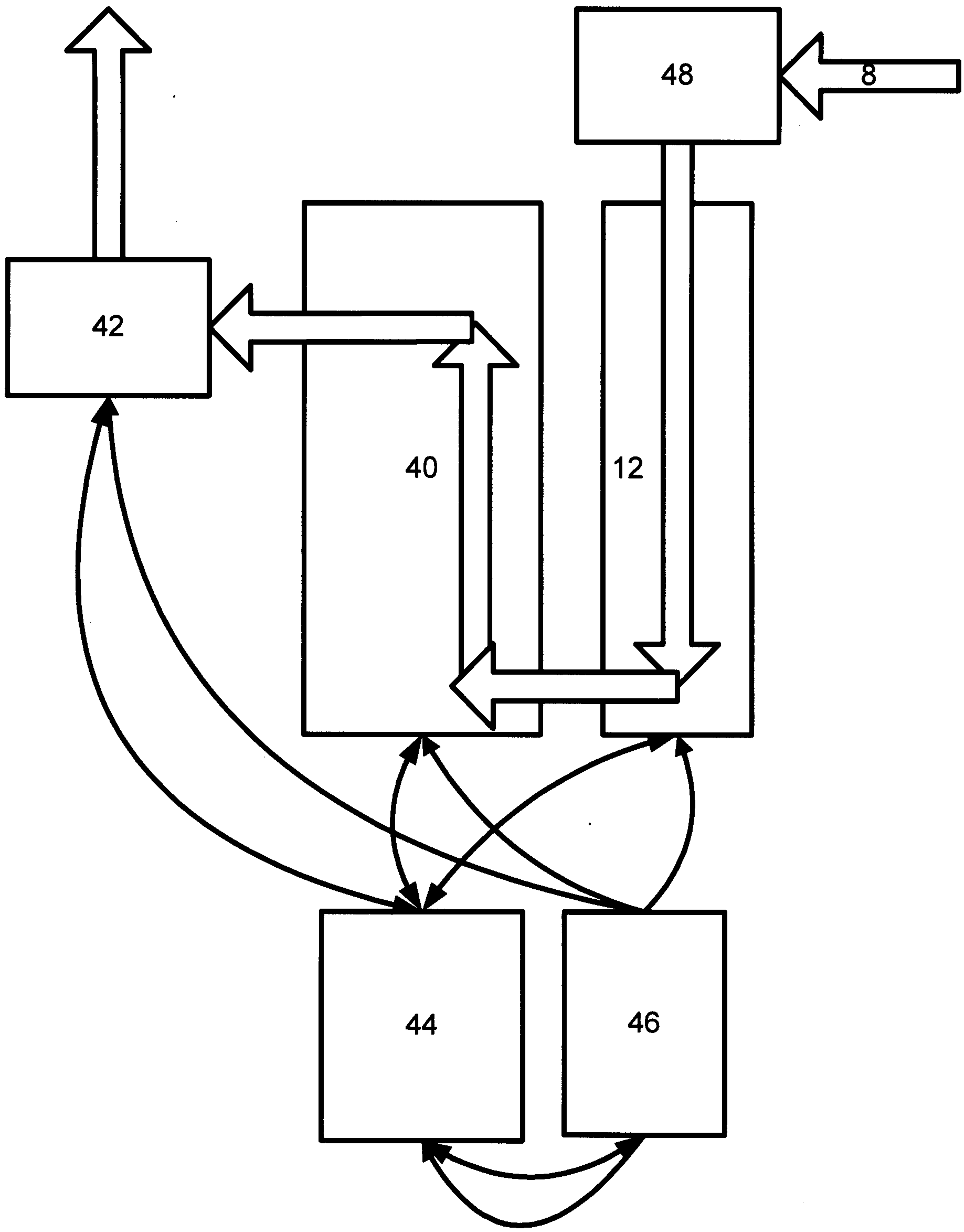
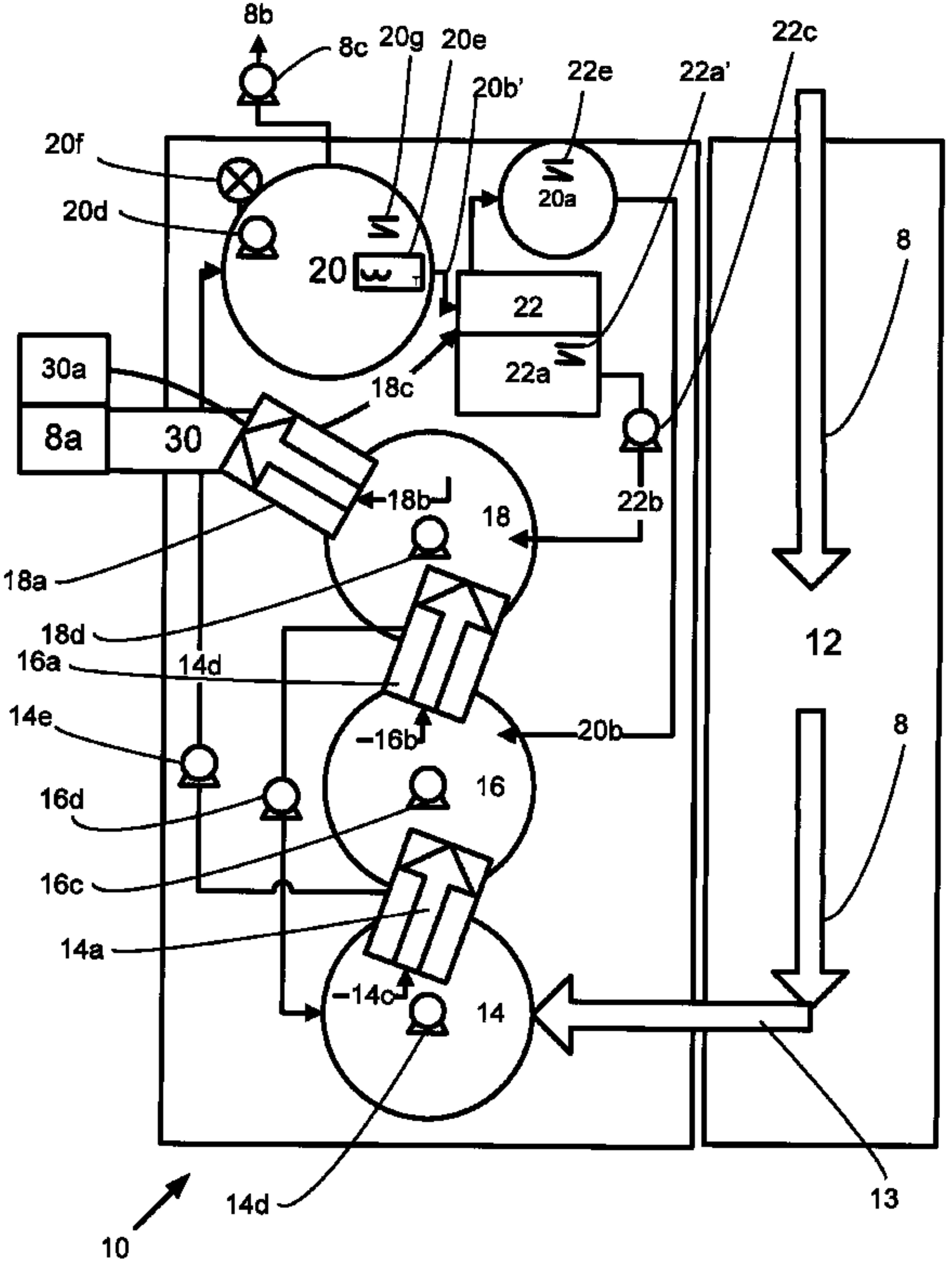


FIGURE 4



8b
8c
20g
20e
22c
20b'
22e
22a'
20f
20a
20d
8
20
22
22a
30a
18c
8a
30
22b
18b
18
18a
18d
12
14d
16a
14e
20b
8
16b
16d
16
16c
14a
14c
14
14d
13
10