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(54) Title: SIMULATED MOVING BED SEPARATORS AND METHODS FOR ISOLATING A DESIRED COMPONENT

(57) Abstract: A simulated moving bed separator and methods for isolating a desired component are provided. A method includes removing an extract from an extract bed of the simulated moving bed separator, where the extract includes the desired component, and where the simulated moving bed separator includes a plurality of adsorbent beds circularly coupled together. The simulated moving bed separator also includes a distributor and a plurality of conduits fluidly coupling the distributor to the adsorbent beds. The adsorbent beds include the extract bed and a secondary flush bed downstream from the extract bed. A secondary flush conduit is flushed with a secondary flush fluid while removing extract from the extract bed, where the secondary flush conduit fluidly couples the secondary flush bed with the distributor. The flush fluid includes the extract.

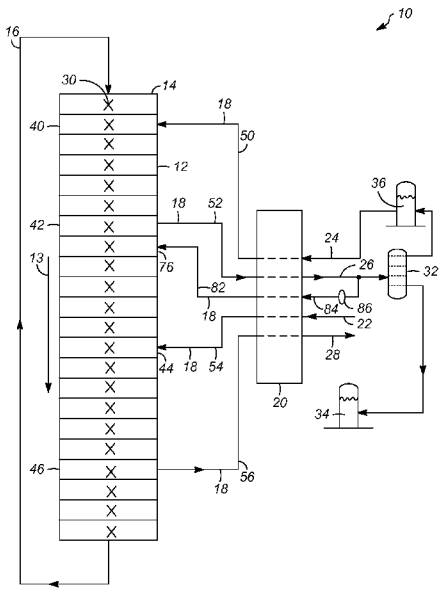


FIG. 1

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SIMULATED MOVING BED SEPARATORS AND METHODS FOR ISOLATING A DESIRED COMPONENT

STATEMENT OF PRIORITY

[0001] This application claims priority to U.S. Application No. 14/319,548 which was filed June 30, 2014, the contents of which are hereby incorporated by reference in its entirety.

TECHNICAL FIELD

[0002] The present disclosure generally relates to methods and apparatuses for isolating a desired component from a mixed feed, and more particularly relates to methods and simulated moving bed separators for isolating a desired component from a mixed feed using selective adsorption.

BACKGROUND

[0003] Selective adsorption can separate a desired component from a feed mixture by adsorbing the desired component while letting other components in the mixture flow by. The other components are referred to herein as "undesired components" to differentiate them from the desired component, but the undesired components may be used for other purposes or processes and therefore be desirable in their own right. An adsorption separator may use an adsorbent that has a higher affinity for the desired component than for the undesired components in the mixture, so the desired component is adsorbed on the surface and within pores, cavities, or other areas of the adsorbent. The adsorbent may adsorb some of the desired component, the undesired components, and other compounds, but the more preferred compounds are adsorbed more readily. Selective adsorption can also proceed by adsorbing undesired components and allowing the desired component to flow through the adsorbent for collection. In this description, the desired component is adsorbed by the adsorbent, but this description is also applicable to embodiments where the undesired components are adsorbed and the desired component flows through the adsorbent.

[0004] As the mixture flows over the adsorbent, the desired component is adsorbed so the fluid passing through the adsorbent has a lower concentration of the desired

component, and therefore a higher concentration of other components. This adsorption process diminishes after a period of time because the available adsorption sites on the adsorbent are taken up. The undesired components in the mixture may then be drained or displaced from the adsorbent in a purification process. Additional fluid flowing through the adsorption bed pushes the undesired components out. A desorbent may then be introduced into the adsorbent bed, where the adsorbent preferentially adsorbs the desorbent over the desired component. The desorbent displaces the desired component from the adsorbent in a desorption process, and the desired component can then be collected with some excess desorbent.

[0005] A moving bed adsorption separator uses a plurality of adsorption beds filled with adsorbent, and the adsorption beds are passed through different "zones" for different process steps. For example, a first zone may introduce the mixed feed to the adsorption bed to remove the desired component, and a second zone may be a purification zone where the undesired components are removed in a raffinate. A desorption zone may follow the purification zone, where the desired component is desorbed and recovered. In a simulated moving bed separator using an adsorbent, a plurality of adsorption beds are fluidly connected together and fixed in position. Some simulated moving bed separators use a plurality of adsorption beds fluidly coupled in a circular manner, so fluids flow through the adsorption beds in a loop. i.e., fluid flows from the first adsorption bed into the second adsorption bed, fluid flows from the second adsorption bed into the third adsorption bed, and so on, and fluid from the last adsorption bed flows into the first adsorption bed. The adsorption beds pass through the various zones by changing or shifting feed and take-off locations from one adsorption bed to the next, where the relative position of the feed and take-off locations determine the zone each adsorption bed is in. For example, a plurality of conduits fluidly couple the adsorption beds to a distributor, and the distributor shifts or changes the feed bed, or the adsorption bed where the feed stream is introduced to the adsorption beds. The distributor changes the feed bed from one adsorption bed to an adjacent adsorption bed, and also changes other feeds and extractions from the adsorption beds. After a period of time, the distributor changes the feed bed again, such that each adsorption bed serves as the feed bed in turn.

[0006] The desired component is removed from the simulated moving bed separator in an extract, where the desorbent is fed into the adsorption beds to displace the desired

component, as described above. The extract includes the desired component and the desorbent, which can be separated by distillation. The distributor changes the conduit used to remove the extract, and that conduit is rinsed before use to increase the purity of the recovered product. The conduit is typically rinsed with the desorbent because the desorbent will be present in the extract and the distillation system is in place to separate the desorbent from the desired component. However, energy is required to separate the desorbent and the desired component by distillation. The higher the concentration of desorbent, the more energy that is needed for the distillation.

[0007] Accordingly, it is desirable to develop methods and apparatus to separate a desired component from a mixture with a simulated moving bed separator that produces an extract with a higher concentration of desired product than when the extract conduit is rinsed with a desorbent. In addition, it is desirable to reduce the total amount of energy needed to recover the desired product than when the extract conduit is rinsed with a desorbent. Furthermore, other desirable features and characteristics of the present embodiment will become apparent from the subsequent detailed description and the appended claims, taken in conjunction with the accompanying drawings and this background.

BRIEF SUMMARY

[0008] Simulated moving bed separators and methods for isolating a desired component from a mixed feed are provided. In an exemplary embodiment, a method includes removing an extract from an extract bed of the simulated moving bed separator, where the extract includes the desired component, and where the simulated moving bed separator includes a plurality of adsorbent beds circularly coupled together. The simulated moving bed separator also includes a distributor and a plurality of conduits fluidly coupling the distributor to the adsorbent beds. The adsorbent beds include the extract bed and a secondary flush bed downstream from the extract bed. A secondary flush conduit is flushed with a secondary flush fluid while removing extract from the extract bed, where the secondary flush conduit fluidly couples the secondary flush bed with the distributor. The flush fluid includes the extract.

[0009] In accordance with another exemplary embodiment, a method for separating a desired component from a mixed fee stream includes introducing the mixed feed into a

feed bed of a simulated moving bed separator, where the mixed feed includes the desired component and an undesired component. The simulated moving bed separator includes a plurality of adsorbent beds fluidly coupled together in a circular manner, a distributor, and a plurality of conduits fluidly coupling the distributor to the adsorbent beds. A raffinate is removed from a raffinate bed, where the raffinate includes the undesired components. A desorbent is introduced to a desorbent bed, and an extract is removed from an extract bed, where the extract includes the desired component and the desorbent. A secondary flush conduit is flushed with a flush fluid that is 1 mass percent or more desorbent and 80 mass percent or more desired component. The secondary flush conduit fluidly couples the distributor with the adsorbent bed downstream from the extract bed.

[0010] In accordance with a further exemplary embodiment, simulated moving bed separator includes a plurality of adsorbent beds fluidly coupled together in a circular manner, where the adsorbent beds include a raffinate bed, a desorbent bed, a feed bed, an extract bed, and a secondary flush bed. The simulated moving bed separator also includes a distributor and a plurality of conduits fluidly coupling the adsorbent beds to the distributor. The conduits include a raffinate conduit fluidly coupled to the distributor and to the raffinate bed, a desorbent conduit fluidly coupled to the distributor and to the desorbent bed, a feed conduit fluidly coupled to the distributor and to the feed bed, an extract conduit fluidly coupled to the distributor and to the extract bed, and a secondary flush conduit fluidly coupled to the distributor and to the secondary flush bed. The extract bed is configured to produce an extract, and the distributor is configured to introduce the extract into the secondary flush conduit.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Various embodiments will hereinafter be described in conjunction with the following drawing figures, wherein like numerals denote like elements, and wherein:

[0012] FIG. 1 is a schematic diagram of an exemplary embodiment of a simulated moving bed separator, where only the conduits for the mixed feed, desorbent, raffinate, extract, and secondary flush are illustrated;

[0013] FIG. 2 is a schematic diagram of an alternate embodiment of a simulated moving bed separator with two stacks, where all the conduits are illustrated;

[0014] FIGS. 3A and 3B are schematic diagrams of an exemplary embodiment of a simulated moving bed separator, where FIG. 3A is before a valve step, and FIG. 3B is after the valve step; and

[0015] FIGS. 4A and 4B are schematic diagrams of the extract and secondary flush portion of a simulated moving bed separator, where FIG. 4A is before a valve step, and FIG. 4B is after the valve step.

DETAILED DESCRIPTION

[0016] The following detailed description is merely exemplary in nature and is not intended to limit the application and uses of the embodiment described. Furthermore, there is no intention to be bound by any theory presented in the preceding background or the following detailed description.

[0017] The various embodiments described herein relate to methods and apparatuses for isolating a desired component from a mixed feed stream. Simulated moving bed separators are known in the industry, such as the simulated moving bed separator known by the trademark SORBEX® available from UOP, LLC of 25 East Algonquin Road, Des Plaines, Illinois 60016 U.S.A. A simulated moving bed separator includes a plurality of adsorbent beds, where a mixed feed is introduced to one of the adsorbent beds referred to as a feed bed, desorbent is introduced to an adsorbent bed referred to as a desorbent bed, extract with the desired component and desorbent is withdrawn from an extract bed, and raffinate with the undesired components is withdrawn from a raffinate bed. A plurality of conduits fluidly couples the adsorbent beds with a distributor that controls the flows to and from the various adsorbent beds. The adsorbent beds used to introduce and withdraw material are periodically changed in a rotational manner, where the distributor changes the flows to the appropriate conduits. When the adsorbent bed change is made, a first extract bed will change to a second extract bed, where the second extract bed is downstream from the first extract bed. Before the change, the conduit to the second extract bed is flushed to eliminate or reduce possible contaminants in the conduit that could be incorporated into the extract. The conduit to the second extract bed is flushed with a flush fluid that includes the extract, and the extract includes the desired component and the desorbent as described above. The flush fluid is carried with, and incorporated into, the extract. The total concentration of desorbent in the extract is reduced by flushing the conduit with

extract instead of with desorbent, because the extract has a lower concentration of desorbent than the essentially pure desorbent that may otherwise be used for the flush. Separating the desorbent from the desired component by distillation requires less energy if there is less desorbent to be separated.

[0018] Referring to an exemplary embodiment in FIG. 1, a simulated moving bed separator **10** includes a plurality of adsorbent beds **12** fluidly coupled together in a circular manner. Each adsorbent bed **12** receives fluid from the adsorbent bed **12** directly upstream from it, and each adsorbent bed **12** transfers fluid to the adsorbent bed **12** directly downstream from it. The direction of fluid flow through the adsorbent beds **12** is represented by arrow **13**. Therefore, each adsorbent bed **12** is directly coupled to two other adsorbent beds **12**, the one directly upstream from it and the one directly downstream from it. The adsorbent beds **12** may be connected in one continuous stack **14**, as illustrated in FIG. 1, with a recirculation line **16** transporting fluid from the adsorbent bed **12** at the bottom of the stack **14** to the adsorbent bed **12** at the top of the stack **14**, or from the adsorbent bed **12** at the top of the stack **14** to the adsorbent bed **12** at the bottom of the stack **14** in embodiments with upwards flow. The fluid flows through the adsorbent beds **12** in the stack **14**, and is then recirculated from the last adsorbent bed **12** to the first adsorbent bed **12** by the recirculation line **16**, so the flow is circular. In alternate embodiments, the adsorbent beds **12** may be in two or more stacks **14** with two or more recirculation lines **16** configured to carry fluid through the adsorbent beds **12** in a loop, as illustrated in the exemplary embodiment in FIG. 2, to be discussed in more detail below. The stacks **14** may include one, two, or more adsorbent beds **12** in various embodiments, but the flow is circular regardless of the number of stacks **14** in the simulated moving bed separator **10**.

[0019] Referring to FIGS. 1 and 2, a plurality of conduits **18** fluidly couples the plurality of adsorbent beds **12** to a distributor **20**. The distributor **20** moves the locations of the liquid input and output to the stack **14** by directing the appropriate fluid flow to the proper conduit **18**, and therefore to the proper adsorbent bed **12**. In some embodiments, the distributor **20** is a rotary valve, as is understood by those skilled in the art, but other types of distributors **20** can be used in alternate embodiments, such as a plurality of individual valves (not illustrated) that may be computer controlled. The conduits **18** have a volume, where the volume of the conduit **18** is the volume within the conduit **18** from the

distributor **20** to the adsorbent bed **12**. The distance between the distributor **20** and the various adsorbent beds **12** may vary from one adsorbent bed **12** to the next, so one or more of the conduits **18** may have a larger volume than others, and one or more conduits **18** will have the largest conduit volume. In some embodiments, the conduits **18** all have essentially the same diameter, so the conduit **18** with the longest length between the distributor **20** and the adsorbent bed **12** will have the largest volume. However, in other embodiments, the conduits **18** may have different diameters. If all the conduits **18** have the same volume, that volume is the largest volume for the conduits **18**.

[0020] The distributor **20** directs fluid flow through the conduits **18** to the input and output locations, or adsorbent beds **12** used for the input or output of fluids. After a specified time period, which is called the step time in some embodiments, the distributor **20** advances one index and redirects the inputs and outputs to the adsorbent bed **12** directly downstream from the one previously in use in what is called a valve step. When the adsorbent bed **12** used for an input or output has completed an entire loop it is called a valve cycle, so each adsorbent bed **12** is used for each input and each output in one valve cycle. In many embodiments, there are at least two input streams and two output streams employed in the procedure, including a mixed feed stream **22**, a desorbent stream **24**, an extract stream **26**, and a raffinate stream **28**. The locations at which the mixed feed stream **22** and the desorbent stream **24** enter the simulated moving bed separator **10** and the extract stream **26** and the raffinate stream **28** leave the simulated moving bed separator **10** are simultaneously shifted in the same direction by the distributor **20**. Each shift in location of these input or output points delivers or removes liquid from a different adsorbent bed **12** within the simulated moving bed separator **10**.

[0021] In many embodiments, the volume of the plurality of adsorbent beds **12** is constant, such as within 5% of an average adsorbent bed volume, and the step time for each valve step is also constant. In alternate embodiments, the volume of the adsorbent beds **12** varies from one adsorbent bed **12** to the next, and the step time may vary during a valve cycle. In an exemplary embodiment with a constant step time, the step time is 60 to 90 seconds, but in other embodiments the step time is 15 minutes to an hour, and other step times are also possible.

[0022] The adsorbent beds **12** include an adsorbent **30**, and the type of adsorbent **30** varies depending on the use of the simulated moving bed separator **10**. In an exemplary embodiment, the simulated moving bed separator **10** is used to separate para-xylene as a desired component **34** from a mixed xylene stream, where the ortho- and meta- xylene are undesired components. The mixed xylene stream may include other compounds besides xylene, such as ethyl benzene. As mentioned above, ortho- and meta- xylene have many beneficial uses and are valuable, so the reference to ortho- and meta- xylene as undesirable components is merely to distinguish them from the desired component **34**, and not to disparage the value of ortho- and meta- xylene. In embodiments where the desired component **34** is para-xylene, the adsorbent **30** may be a zeolitic material that preferentially adsorbs para-xylene over meta-xylene, ortho-xylene, and ethylbenzene. In another embodiment where the desired component **34** is meta-xylene, the adsorbent **30** is a zeolitic material that preferentially adsorbs meta-xylene over para-xylene, ortho-xylene, and ethylbenzene. In yet another embodiment, the simulated moving bed separator **10** is used to separate olefins from paraffins where the desired component **34** is olefins, and the adsorbent **30** is a zeolitic material that preferentially adsorbs olefins over paraffins. In still another embodiment, the simulated moving bed separator **10** is used to separate normal paraffins from branched paraffins where the desired component **34** is normal paraffins, and the adsorbent **30** is a zeolitic material that preferentially adsorbs normal paraffins over branched paraffins. Many other uses and adsorbents **30** are possible in various embodiments, such as the separation of pharmaceutical materials, enzymes or other biological materials, or a wide variety of compounds. In various embodiments, the adsorbent **30** is charcoal, silica gel, ion-exchange resins, or many other materials.

[0023] The extract stream **26** includes the extract, where the extract includes the desired component **34** and desorbent **36**. In an exemplary embodiment, the extract is 50 mass percent or more desorbent **36**, and 50 mass percent or less desired component **34**, but in alternate embodiments the extract is 20 to 80 mass percent desorbent **36** and 80 to 20 mass percent desired component **34**. The extract stream **26** is transferred to an extract distillation column **32** to separate the desired component **34** from the desorbent **36**. The extract stream **26** may be stored, such as in a tank, drums, tote bins, or other containers (not illustrated) before distillation, but the extract stream **26** flows directly to the extract distillation column **32** in some embodiments. In an exemplary embodiment, the desired

component **34** is para-xylene and the desorbent **36** is toluene, but in other embodiments the desorbent **36** can be diethyl benzene or other compounds. When the desorbent **36** is toluene, the desorbent **36** has a lower boiling point than the desired component **34**, para-xylene, so the toluene is vaporized and lifted in the extract distillation column **32**. Lifting the desorbent **36** requires energy, so the lower the concentration of toluene in the extract stream **26**, the less energy required to recover a set quantity of the desired component **34**. In embodiments where the desorbent **36** has a higher boiling point than the desired component **34**, the desired component **34** is lifted in the extract distillation column **32**, but the desorbent **36** is still heated and processed so higher concentrations of desorbent **36** still increase the energy required in the extract distillation column **32**. The desorbent **36** is re-used in the simulated moving bed separator **10** in many embodiments, and the desired component **34** is removed from the system.

[0024] In an exemplary embodiment, the desorbent **36** from the desorbent stream **24** is introduced to the stack **14** in a desorbent bed **40**, where the desorbent bed **40** is one of the adsorbent beds **12**. The extract is removed from the stack **14** in an extract bed **42**, where the extract bed **42** is one of the adsorbent beds **12** downstream from the desorbent bed **40**. In an exemplary embodiment, only one extract stream **26** is removed from the stack **14** at a time, so all the extract being removed from the stack **14** at one time has essentially the same composition. In an alternate embodiment, there is only one feed bed **44** in the stack **14** at any one time, so all the mixed feed is added to the stack **14** in the same feed bed **44**. In an alternate embodiment, there is only one mixed feed stream **22** introduced to the stack **14** at any one time. The mixed feed stream **22** is introduced to the stack **14** in a feed bed **44**, where the feed bed **44** is downstream from the extract bed **42**. Therefore, the extract bed **42** is between the desorbent bed **40** and the feed bed **44**. The mixed feed stream **22** includes the mixed feed, where the mixed feed includes the desired component **34** and the undesired components. The raffinate is removed from a raffinate bed **46**, where the raffinate bed **46** is an adsorbent bed **12** positioned downstream from the feed bed **44** and upstream from the desorbent bed **40**. As such, the desorbent bed **40** is between the raffinate bed **46** and the extract bed **42**, the extract bed **42** is between the desorbent bed **40** and the feed bed **44**, the feed bed **44** is between the extract bed **42** and the raffinate bed **46**, and the raffinate bed **46** is between the feed bed **44** and the desorbent bed **40**. A desorbent conduit **50**, an extract conduit **52**, a feed conduit **54**, and a raffinate conduit **56** are

conduits **18** that fluidly couple the desorbent bed **40**, the extract bed **42**, the feed bed **44**, and the raffinate bed **46**, respectively, to the distributor **20**. With each valve step, the desorbent conduit **50**, the extract conduit **52**, the feed conduit **54**, and the raffinate conduit **56** change, where FIG. 1 illustrates the conduits **18** with fluid flow, and FIG. 2 illustrates all the conduits 18, including those without any fluid flow.

[0025] Referring to the exemplary embodiment illustrated in FIGS. 3A and 3B, the inputs and outputs to the stack **14** are shifted downstream to the adjacent adsorbent bed **12** in a valve step, where FIG. 3A illustrates the inputs and outputs before the valve step, and FIG. 3B illustrates the inputs and outputs after the valve step. Before the valve step, the desorbent bed **40** is a first desorbent bed **60**, and after the valve step the desorbent bed **40** is a second desorbent bed **62**, where the second desorbent bed **62** is directly downstream from the first desorbent bed **60**. "Directly downstream" means the adjacent downstream adsorbent bed **12**, so fluids flow directly from the upstream adsorbent bed **12** to the adjacent downstream adsorbent bed **12**. In many embodiments, the second desorbent bed **62** is not used for introducing desorbent **36** into the stack **14** before the valve step, so before the valve step the second desorbent bed **62** is not one of the named desorbent bed **40**, extract bed **42**, feed bed **44**, or raffinate bed **46**. In the same manner, first desorbent bed **60** is not used for introducing desorbent **36** into the stack **14** after the valve step, so the first desorbent bed **60** reverts to simply one desorbent bed **40** in the stack **14** after the valve step. Therefore, each desorbent bed **40** will be a first desorbent bed **60** and a second desorbent bed **62** during one valve cycle, or complete loop of the stack **14**, as mentioned above. In the same manner as for the desorbent bed **40** described above, the extract bed **42** is a first extract bed **64** before the valve step and a second extract bed **66** after the valve step; the feed bed **44** is a first feed bed **68** before the valve step and a second feed bed **70** after the valve step; and the raffinate bed **46** is a first raffinate bed **72** before the valve step and a second raffinate bed **74** after the valve step.

[0026] The exemplary embodiment in FIGS. 4A and 4B illustrate the portion of the stack **14** that includes the extract bed **42** and a secondary flush bed **76** directly downstream from the extract bed **42**, but does not include the desorbent bed **40**, the feed bed **44**, or the raffinate bed **46** illustrated in FIGS. 3A and 3B. The secondary flush bed **76** is a first secondary flush bed **88** before the valve step, and a second secondary flush bed **90** after the valve step, and a secondary flush conduit **82** is a first secondary flush conduit **92**

before the valve step and a second secondary flush conduit **94** after the valve step, as described above. FIG. 4A illustrates an embodiment before a valve step, and FIG. 4B illustrates the same embodiment after the valve step. In alternate embodiments (not illustrated), the secondary flush bed **76** is downstream from the extract bed **42**, but the secondary flush bed **76** may not be directly downstream from the extract bed **42**. For example, the secondary flush bed **76** may be downstream from the extract bed **42**, where one or more intervening adsorbent beds **12** are positioned between the extract bed **42** and the secondary flush bed **76** so long as no fluids flow to or from the intervening adsorbent beds **12** through the associated conduits **18** and the distributor **20**.

[0027] Reference is made to FIGS. 3A, 3B, 4A, and 4B. A first extract conduit **78** fluidly couples the first extract bed **64** to the distributor **20**, and a second extract conduit **80** fluidly couples the second extract bed **66** to the distributor **20**. The first secondary flush conduit **92** fluidly couples the first secondary flush bed **88** to the distributor **20**, and the second secondary flush conduit **94** fluidly couples the second secondary flush bed **90** to the distributor **20**. The first secondary flush bed **88** is the adsorbent bed **12** directly downstream from the first extract bed **64**, and the second secondary flush bed **90** is the adsorbent bed **12** directly downstream from the second extract bed **6**6. Therefore, the first secondary flush conduit **92** before the valve step becomes the second extract conduit **80** when the valve step occurs, and the first secondary flush bed **88** before the valve step becomes the second extract bed **66** after the valve step.

[0028] To prevent or minimize contamination of the extract stream **26**, the secondary flush conduit **82** is flushed with a secondary flush fluid from a secondary flush fluid stream **84**, where the secondary flush fluid includes the extract. In an exemplary embodiment, the secondary flush fluid is 99 mass percent or more extract, but the secondary flush fluid may be 80 mass percent or more extract, or 90 mass percent or more extract, or 95 mass percent or more extract in alternate embodiments. In alternate embodiments, the flush fluid is 50 mass percent or more desorbent **36**, and 50 mass percent or less desired component **34**, or the flush fluid is 20 to 80 mass percent desorbent **36** and 80 to 20 mass percent desired component **34**, where the desorbent **36** and desired component **34** may be from the extract or from other sources. The extract for the secondary flush fluid may be withdrawn from the extract stream **26** between the distributor **20** and the extract distillation column **32**, as illustrated in exemplary

embodiments in FIGS. 1 and 2 with continuing reference to FIGS. 3A, 3B, 4A, and 4B. An extract pump **86** may be used to pressurize the extract used in the secondary flush fluid. The extract may be pumped from the extract stream **26**, or from a storage location for the extract.

[0029] In an exemplary embodiment, the secondary flush conduit 82 is flushed with a flush volume of the secondary flush fluid, where the flush volume is within 5 volume percent of the volume of the conduit **18** with the largest volume. Each conduit **18** will serve as the secondary flush conduit **82** at some point within a valve cycle, so a single flush volume that is essentially equal to the largest conduit volume is adequate to flush the contents of the secondary flush conduit **82** prior to use as the extract conduit **52**. In an alternate embodiment, the flush volume is within 5 volume percent of the volume of the secondary flush conduit **82**, so the flush volume may be varied for different conduits **18** that have different volumes. Any excess secondary flush fluid flows into the secondary flush bed **76**, and is then withdrawn from the stack **14** with the extract after the subsequent valve step. The use of extract in the secondary flush fluid reduces the total concentration of desorbent **36** in the extract as compared to a similar secondary flush using desorbent **36**. The simulated moving bed separator **10** may include other flushes of various conduits **18** in various embodiments (not illustrated), as is understood by those skilled in the art.

SPECIFIC EMBODIMENTS

[0030] While the following is described in conjunction with specific embodiments, it will be understood that this description is intended to illustrate and not limit the scope of the preceding description and the appended claims.

[0031] A first embodiment of the invention is a method of separating a desired component from a mixed feed stream, the method comprising the steps of removing an extract from an extract bed of a simulated moving bed separator, wherein the extract comprises the desired component, wherein the simulated moving bed separator comprises a plurality of adsorbent beds circularly coupled together, a distributor, and a plurality of conduits fluidly coupling the distributor to the plurality of adsorbent beds, and wherein the plurality of adsorbent beds comprises the extract bed and a secondary flush bed downstream from the extract bed; and flushing a secondary flush conduit with a secondary flush fluid while removing extract from the extract bed, wherein the secondary

flush conduit fluidly couples the secondary flush bed with the distributor, and wherein the secondary flush fluid comprises the extract. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph wherein removing the extract from the extract bed comprises removing the extract from the extract bed wherein the secondary flush bed is directly downstream from the extract bed. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph further comprising changing the extract bed from a first extract bed to a second extract bed in a valve step, wherein the second extract bed is the adsorbent bed directly downstream from the first extract bed such that the second extract bed is the same adsorbent bed as the secondary flush bed before the valve step. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph wherein removing the extract from the extract bed comprises removing the extract from the extract bed wherein the plurality of adsorbent beds comprise an adsorbent, and wherein the adsorbent is a zeolitic adsorbent that preferentially adsorbs para-xylene over meta-xylene, ortho-xylene, and ethylbenzene, and wherein the desired component is para-xylene. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph wherein removing the extract from the extract bed comprises removing the extract from the extract bed wherein the plurality of adsorbent beds comprise an adsorbent, and wherein the adsorbent is a zeolitic adsorbent that preferentially adsorbs meta-xylene over para-xylene, ortho-xylene, and ethylbenzene, and wherein the desired component is meta-xylene. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph wherein removing the extract from the extract bed comprises removing the extract from the extract bed wherein the plurality of adsorbent beds comprise an adsorbent, and wherein the adsorbent is a zeolitic adsorbent that preferentially adsorbs normal paraffins over branched paraffins, and wherein the desired component is normal paraffins. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph wherein removing the extract from the simulated moving bed separator comprises removing the extract from the simulated moving bed separator wherein the plurality of adsorbent beds comprise an adsorbent, and wherein the adsorbent is a zeolitic adsorbent that preferentially adsorbs

olefins over paraffins. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph further comprising introducing the mixed feed stream into a feed bed, wherein the simulated moving bed separator comprises a single feed bed at any one time, and wherein the mixed feed stream comprises the desired component and an undesired component. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph further comprising introducing the mixed feed into a feed bed, wherein the mixed feed comprises the desired component and an undesired component; introducing a desorbent into a desorbent bed, wherein the extract comprises the desorbent and the desired component; and removing a raffinate from a raffinate bed, wherein the raffinate comprises the undesired component, and wherein the plurality of adsorbent beds comprise the feed bed, the desorbent bed and the raffinate bed. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph wherein introducing the mixed feed stream comprises introducing the mixed feed stream wherein the feed bed is downstream from the extract bed; removing the raffinate comprises removing the raffinate wherein the raffinate bed is downstream from the feed bed; introducing the desorbent comprises introducing the desorbent wherein the desorbent bed is downstream from the raffinate bed; and removing the extract comprises removing the extract wherein the extract bed is downstream from the desorbent bed. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph wherein flushing the secondary flush conduit comprises flushing the secondary flush conduit with the secondary flush fluid, wherein 90 mass percent or more of the secondary flush fluid is the extract. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph wherein flushing the secondary flush conduit comprises pumping extract to the distributor, and wherein the distributor directs the extract to the secondary flush conduit. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph wherein flushing the secondary flush conduit with the secondary flush fluid comprises flushing the secondary flush conduit with a flush volume of the secondary flush fluid, wherein the flush volume is within 5% of a largest conduit volume.

[0032] A second embodiment of the invention is a method for separating a desired component from a mixed feed stream, the method comprising the steps of introducing a mixed feed into a feed bed of a simulated moving bed separator, wherein the mixed feed comprises the desired component and an undesired component, and wherein the simulated moving bed separator comprises a plurality of adsorbent beds fluidly coupled together in a circular manner, a distributor, and a plurality of conduits fluidly coupling the distributor to the plurality of adsorbent beds; removing a raffinate from a raffinate bed of the simulated moving bed separator, wherein the raffinate comprises the undesired component; introducing a desorbent into a desorbent bed of the simulated moving bed separator; removing an extract from an extract bed of the simulated moving bed separator, wherein the extract comprises the desired component and the desorbent, and wherein the plurality of adsorbent beds comprise the feed bed, the raffinate bed, the desorbent bed, and the extract bed; and flushing a secondary flush conduit with a secondary flush fluid, wherein the secondary flush conduit fluidly couples the distributor with the adsorbent bed downstream from the extract bed, wherein 1 mass percent or more of the secondary flush fluid comprises the desorbent, and wherein 20 mass percent or more of the secondary flush fluid comprises the desired component. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph wherein flushing the secondary flush conduit with the secondary flush fluid comprises flushing the secondary flush conduit with the secondary flush fluid wherein the secondary flush conduit fluidly couples the distributor with the adsorbent bed directly downstream from the extract bed. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph wherein removing the extract from the extract bed comprises removing the extract from the extract bed wherein the plurality of adsorbent beds comprise an adsorbent, and wherein the adsorbent is a zeolitic adsorbent that preferentially adsorbs para-xylene over meta-xylene, ortho-xylene, and ethylbenzene, and wherein the desired component is para-xylene. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph wherein introducing the mixed feed into the feed bed comprises introducing the mixed feed into the feed bed, wherein the simulated moving bed separator comprises a single feed bed at any one time. An embodiment of the invention is one, any or all of prior embodiments in this paragraph

up through the second embodiment in this paragraph wherein flushing the secondary flush conduit comprises pumping extract to the distributor for the secondary flush fluid. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph wherein introducing the mixed feed into the feed bed comprises introducing a single mixed feed into the feed bed. A simulated moving bed separator comprising a plurality of adsorbent beds fluidly coupled together in a circular manner, wherein the plurality of adsorbent beds comprise a raffinate bed, a desorbent bed, a feed bed, an extract bed, and a secondary flush bed; a distributor; a plurality of conduits fluidly coupling the plurality of adsorbent beds to the distributor, wherein the plurality of conduits comprise; a raffinate conduit fluidly coupled to the distributor and to the raffinate bed; a desorbent conduit fluidly coupled to the distributor and to the desorbent bed; a feed conduit fluidly coupled to the distributor and to the feed bed; an extract conduit fluidly coupled to the distributor and to the extract bed, wherein the extract bed is configured to produce an extract; a secondary flush conduit fluidly coupled to the distributor and to the secondary flush bed; and wherein the distributor is configured to introduce the extract into the secondary flush conduit.

[0033] While at least one exemplary embodiment has been presented in the foregoing detailed description, it should be appreciated that a vast number of variations exist. It should also be appreciated that the exemplary embodiment or exemplary embodiments are only examples, and are not intended to limit the scope, applicability, or configuration of the application in any way. Rather, the foregoing detailed description will provide those skilled in the art with a convenient road map for implementing one or more embodiments, it being understood that various changes may be made in the function and arrangement of elements described in an exemplary embodiment without departing from the scope, as set forth in the appended claims.

CLAIMS

1. A method of separating a desired component (34) from a mixed feed stream (22), the method comprising the steps of:

removing an extract from an extract bed (42) of a simulated moving bed separator (10), wherein the extract comprises the desired component (34), wherein the simulated moving bed separator (10) comprises a plurality of adsorbent beds (12) circularly coupled together, a distributor (20), and a plurality of conduits (18) fluidly coupling the distributor (20) to the plurality of adsorbent beds (12), and wherein the plurality of adsorbent beds (12) comprises the extract bed (42) and a secondary flush bed (76) downstream from the extract bed (42); and

flushing a secondary flush conduit (82) with a secondary flush fluid while removing extract from the extract bed (42), wherein the secondary flush conduit (82) fluidly couples the secondary flush bed (76) with the distributor (20), and wherein the secondary flush fluid comprises the extract.

2. The method of claim 1 wherein removing the extract from the extract bed (42) comprises removing the extract from the extract bed (42) wherein the secondary flush bed (76) is directly downstream from the extract bed (42).

3. The method of claim 2 further comprising:

changing the extract bed (42) from a first extract bed (64) to a second extract bed (66) in a valve step, wherein the second extract bed (66) is the adsorbent bed (12) directly downstream from the first extract bed (64) such that the second extract bed (66) is the same adsorbent bed (12) as the secondary flush bed (76) before the valve step.

4. The method of claim 1 wherein removing the extract from the extract bed (42) comprises removing the extract from the extract bed (42) wherein the plurality of adsorbent beds (12) comprise an adsorbent (30), and wherein the adsorbent (30) is a zeolitic adsorbent that preferentially adsorbs para-xylene over meta-xylene, ortho-xylene, and ethylbenzene, and wherein the desired component (34) is para-xylene.

5. The method of claim 1 further comprising:

introducing the mixed feed stream (22) into a feed bed (44), wherein the simulated moving bed separator (10) comprises a single feed bed (44) at any one time, and wherein

the mixed feed stream (22) comprises the desired component (34) and an undesired component.

6. The method of claim 1 further comprising:

introducing the mixed feed into a feed bed (44), wherein the mixed feed comprises the desired component (34) and an undesired component;

introducing a desorbent (36) into a desorbent bed (40), wherein the extract comprises the desorbent (36) and the desired component (34); and

removing a raffinate from a raffinate bed (46), wherein the raffinate comprises the undesired component, and wherein the plurality of adsorbent beds (12) comprise the feed bed (44), the desorbent bed (40) and the raffinate bed (46).

7. The method of claim 1 wherein flushing the secondary flush conduit (82) comprises flushing the secondary flush conduit (82) with the secondary flush fluid, wherein 90 mass percent or more of the secondary flush fluid is the extract.

8. The method of claim 1 wherein flushing the secondary flush conduit (82) comprises pumping extract to the distributor (20), and wherein the distributor (20) directs the extract to the secondary flush conduit (82).

9. The method of claim 1 wherein flushing the secondary flush conduit (82) with the secondary flush fluid comprises flushing the secondary flush conduit (82) with a flush volume of the secondary flush fluid, wherein the flush volume is within 5% of a largest conduit volume.

10. A simulated moving bed separator (10) comprising:

a plurality of adsorbent beds (12) fluidly coupled together in a circular manner, wherein the plurality of adsorbent beds (12) comprise a raffinate bed (46), a desorbent bed (40), a feed bed (44), an extract bed (42), and a secondary flush bed (76);

a distributor (20);

a plurality of conduits (18) fluidly coupling the plurality of adsorbent beds (12) to the distributor (20), wherein the plurality of conduits (18) comprise;

a raffinate conduit (56) fluidly coupled to the distributor (20) and to the raffinate bed (46);

a desorbent conduit (50) fluidly coupled to the distributor (20) and to the desorbent bed (40);

a feed conduit (54) fluidly coupled to the distributor (20) and to the feed bed (44);

an extract conduit (52) fluidly coupled to the distributor (20) and to the extract bed (42), wherein the extract bed (42) is configured to produce an extract;

a secondary flush conduit (82) fluidly coupled to the distributor (20) and to the secondary flush bed (76); and

wherein the distributor (20) is configured to introduce the extract into the secondary flush conduit (82).

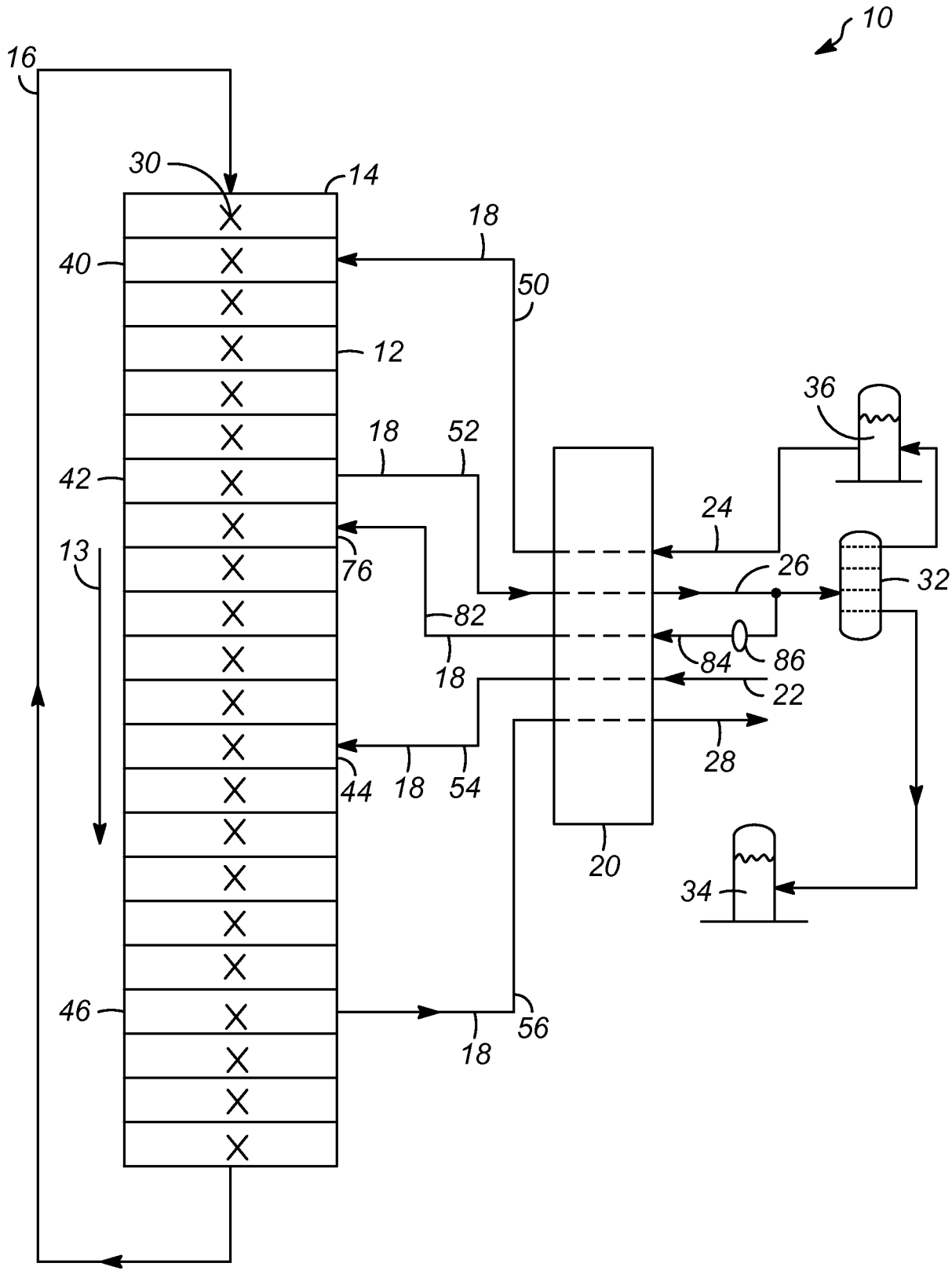

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FIG. 1

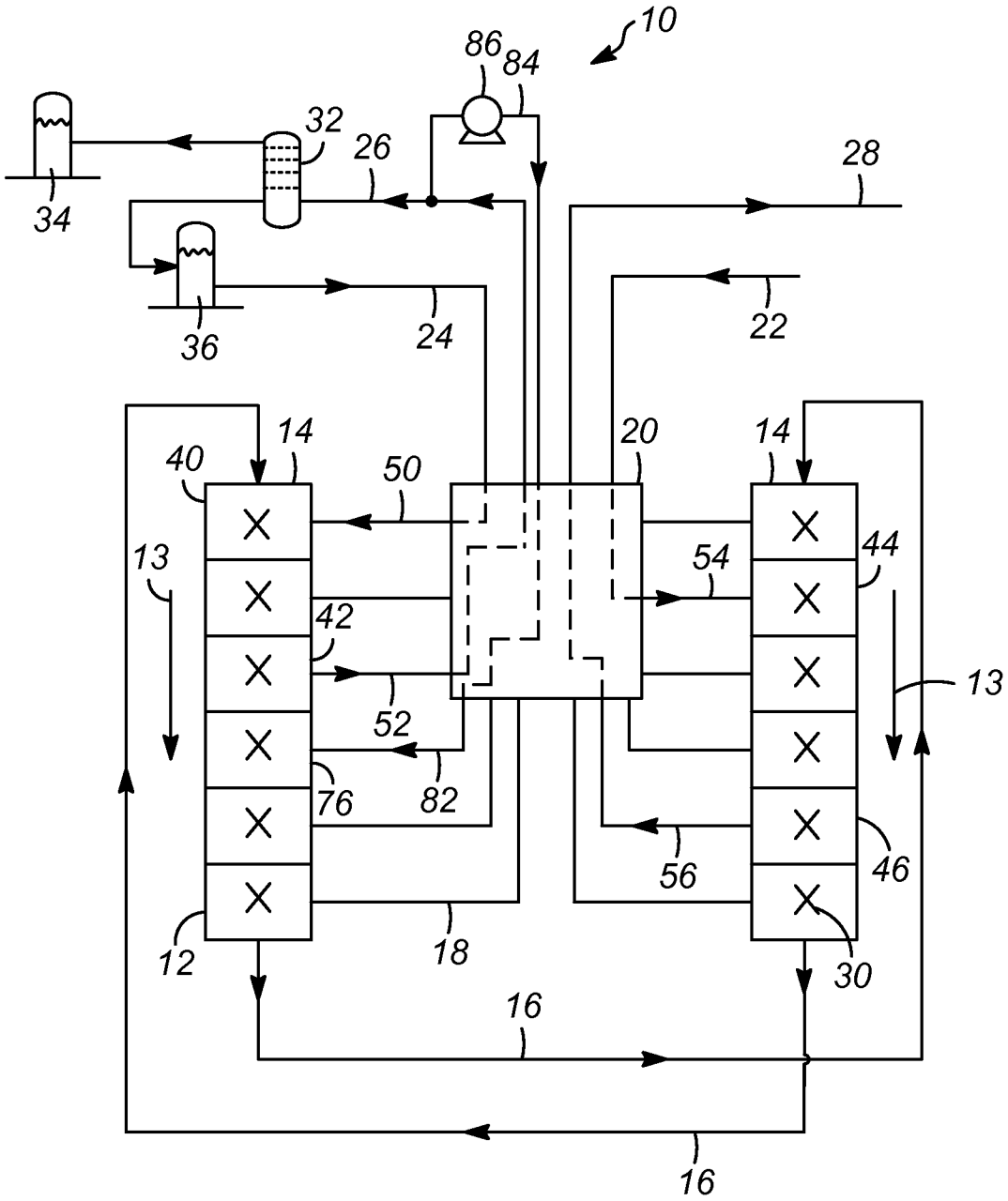

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FIG. 2

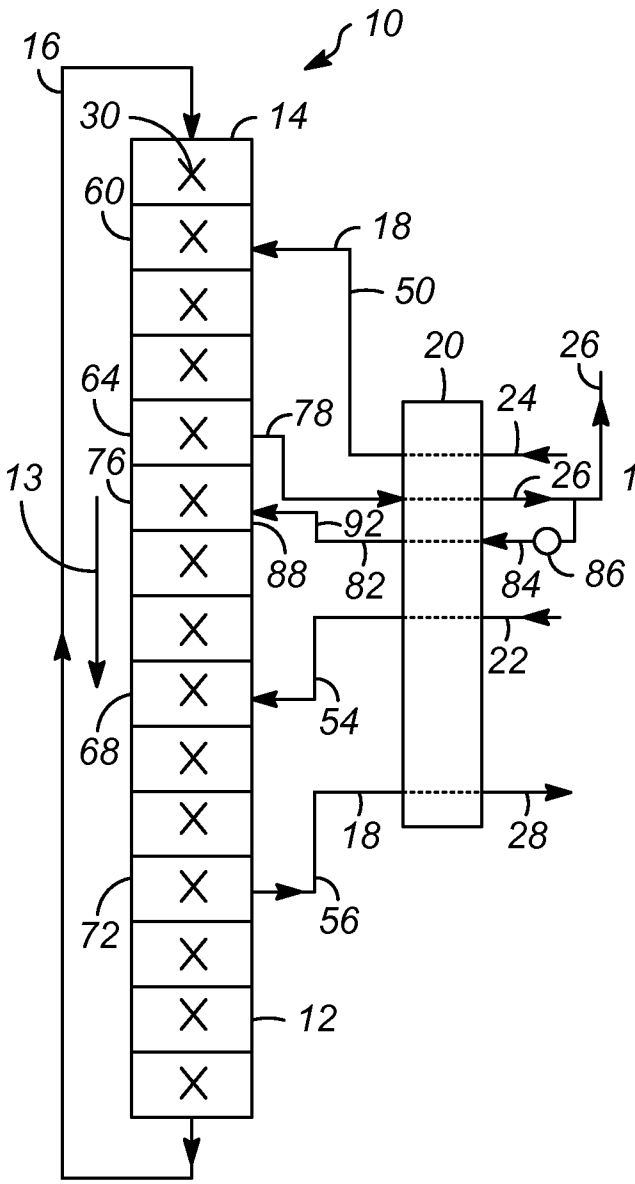

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FIG. 3A

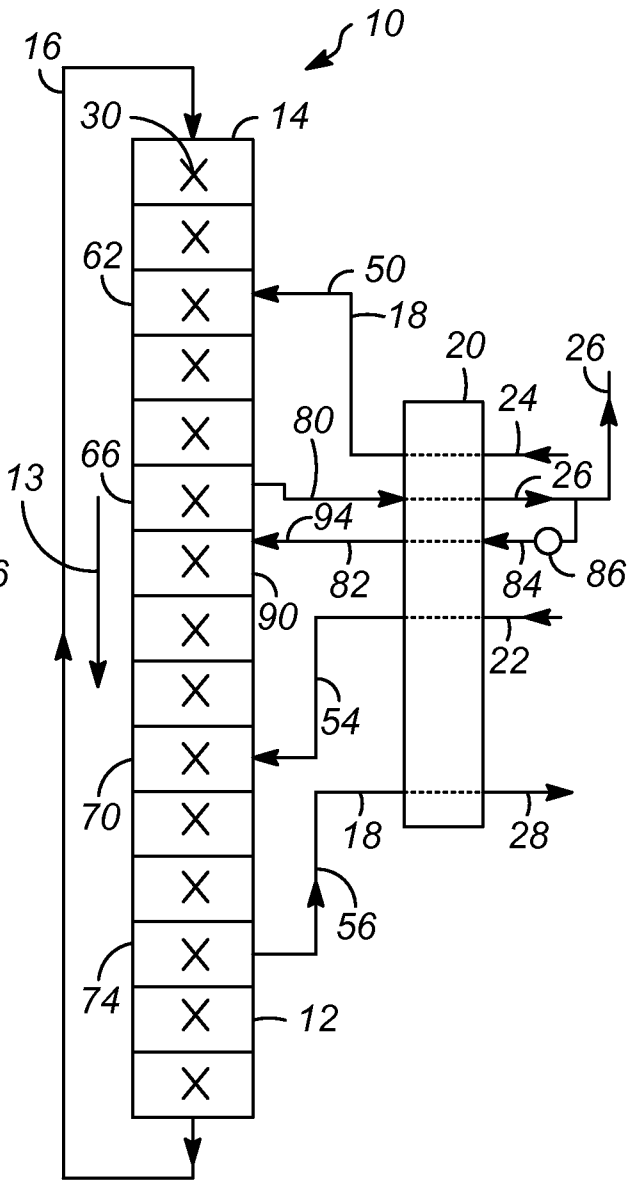

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FIG. 3B

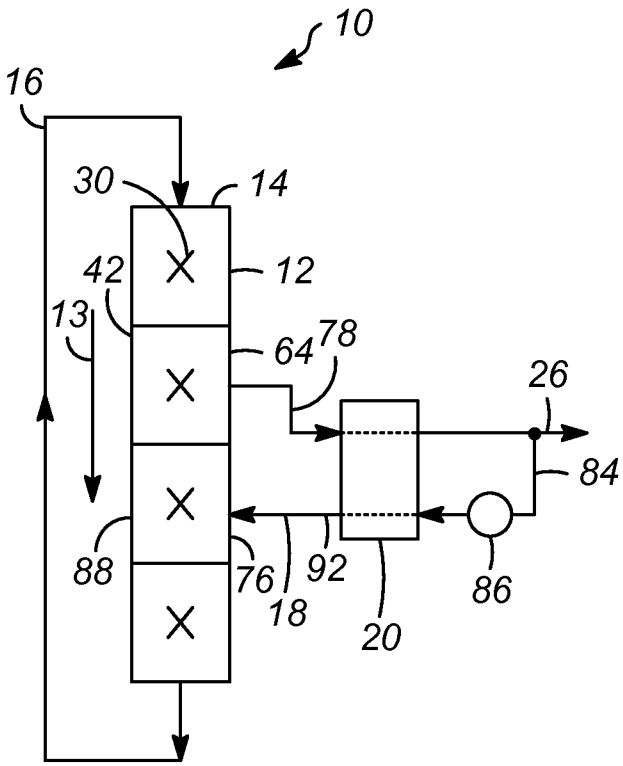

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FIG. 4A

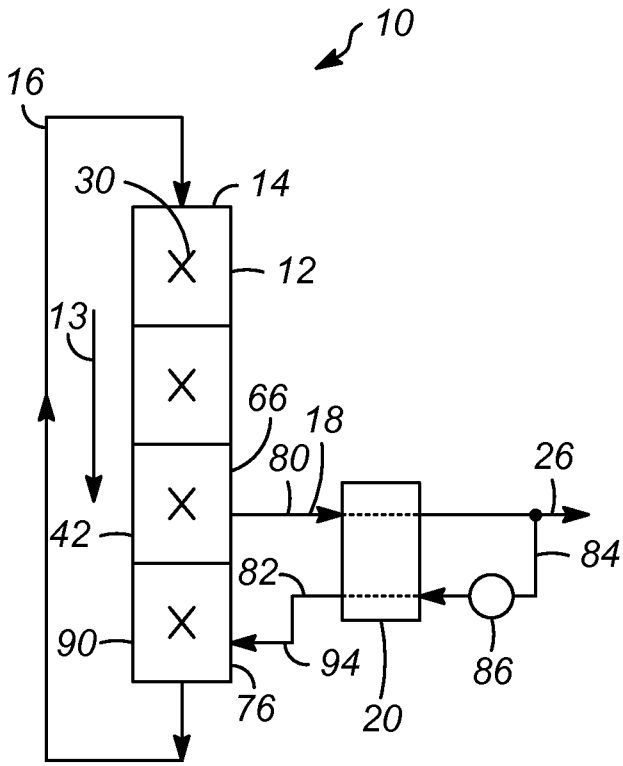

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FIG. 4B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 2015/037584

A. CLASSIFICATION OF SUBJECT MATTER

C10G 55/02 *(2006.01)*
C10G 25/03 *(2006.01)*
C01B 39/00 *(2006.01)*

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)

C10G 55/02, 25/03, C01B 39/00

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)

PatSearch (RUPTO internal), USPTO, PAJ, Esp@cenet, DWPI, EAPATIS, PATENTSCOPE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2009/158242 A2 (UOP LLC et al.) 30.12.2009, abstract, par. [0021], [0031], [0046], [0050], fig. 1, 4	1-10
A	WO 1998/028246 A1 (INSTITUT FRANCAIS DU PETROLE et al.) 02.07.1998	1-10

☐ Further documents are listed in the continuation of Box C.

☐ 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

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"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

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 September 2015 (15.09.2015)	29 October 2015 (29.10.2015)

Name and mailing address of the ISA/RU:	Authorized officer
Federal Institute of Industrial Property, Berezhkovskaya nab., 30-1, Moscow, G-59, GSP-3, Russia, 125993 Facsimile No: (8-495) 531-63-18, (8-499) 243-33-37	I. Eliseeva Telephone No. 499-240-25-91