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(54) Title: EXTRACTOR SYSTEM THAT REMOVES ORGANIC COMPOUNDS FROM EXHAUST GAS USING FEEDSTOCK BEING PROCESSED

(57) Abstract: A liquid-solvent extraction system can extract oil from an oleaginous feedstock using an organic solvent. The extraction system may generate exhaust or vent gases containing residual organic solvent that needs to be treated before discharging the gases to atmosphere. In some configurations, an absorption system is integrated with the extraction system to utilize oil recovered from oleaginous material processed in the extraction system as an absorption medium. The oil absorption medium can treat the exhaust gas produced by the extraction process that extracted the oil in the first instance.

EXTRACTOR SYSTEM THAT REMOVES ORGANIC COMPOUNDS FROM EXHAUST GAS USING FEEDSTOCK BEING PROCESSED

RELATED APPLICATIONS

[0001] This applications claims priority to US Patent Application No. 62/595,211, filed December 6, 2017, the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

[0002] This disclosure relates to extractor system and, more particularly, to extractor system configurations for stripping organic compounds from exhaust gas.

BACKGROUND

[0003] A variety of different industries use extractors to extract and recover liquid substances entrained within solids. For example, producers of oil from renewable organic sources use extractors to extract oil from oleaginous matter, such as soybeans, rapeseed, sunflower seed, peanuts, cottonseed, palm kernels, and corn germ. The oleaginous matter is contacted with an organic solvent within the extractor, causing the oil to be extracted from a surrounding cellular structure into the organic solvent. The organic solvent containing extracted oil can be processed in a distillation column to recover the extracted oil from the solvent.

[0004] In practice, vent gases that are discharged from processing units in a solvent extraction facility may contain residual organic solvent that is desirably removed before discharging the gas to atmosphere. Accordingly, a solvent extraction facility may include a solvent-air separation system that uses mineral oil to absorb entrained organic solvent from the gas being processed. In some configurations, gas is introduced into a mineral oil absorber and rises through a tower packing while mineral oil flows in a counter-current direction through the packing. The entrained organic solvent is absorbed by the mineral oil and desolventized gasses are drawn off through a demister at the top of the absorption column. Solvent laden mineral oil can be collected at the bottom of the absorption column and recycled.

SUMMARY

[0005] In general, this disclosure is directed to systems and techniques for removing entrained organic solvent from gas via absorption, particularly exhaust gas generated from one or more processing units in a solvent extraction process. In some examples, an extraction

system includes an extractor that contacts an oleaginous feedstock with an organic solvent to produce a miscella stream composed of solvent containing extracted oil and a residual solids stream composed of solvent-wet solids having a reduced concentration of oil. The miscella stream may be processed to separate the extracted oil from the solvent, such as by passing the stream through one or more distillation columns and/or stripping vessels. The solvent-wet solids may also be processed to dry the solids and remove residual solvent. These and other processes within the solvent extraction system may generate exhaust gases containing residual organic solvent. For example, steam used to vaporized solvent in a distillation column, stripping vessel, and/or solids desolventizer may be passed through a condenser (e.g., evaporator condenser, vent condenser), to recover condensable liquids. The residual non-condensable gas with any entrained organic solvent may form exhaust gas needing further processing.

[0006] In some configurations according to the present disclosure, the oil recovered from oleaginous material being processed in an extraction system is used as an absorption medium for treating exhaust gas produced by that same process. For example, extracted oil produced by a solvent extraction system that is substantially devoid of residual solvent may be conveyed to an absorption system that also receives exhaust gas from one or more processing units in that same extraction system. The exhaust gas can be contacted with the extracted oil in an absorption column, causing at least a portion (e.g., substantially all) of the entrained organic solvent in the exhaust gas to absorb into the oil. The amount of entrained organic solvent absorbed from the exhaust gas may be suitable to allow the processed exhaust gas to be discharged to the atmosphere. The extracted oil containing absorbed organic solvent from the exhaust gas can be further processed, for example through distillation and/or stripping, to remove the organic solvent from the oil. The oil can then be discharged, e.g., for downstream use, recycling within the absorption system, or other use.

[0007] While a variety of different absorption column configurations can be used, in some examples, the absorption column includes valve trays, such as fixed valve trays. Such a hardware configuration may help promote uniform mixing between the extracted oil passed through the absorption column and the exhaust gas being processed. This may allow reduced steam consumption and operating temperatures within the column, reducing fouling in the column and oil loss through vaporization that may otherwise occur if operating at higher temperatures. Hardware configurations that help minimize fouling may be especially useful for systems that use extracted oil as an absorption medium as opposed to more purified and refined mineral oil.

[0008] By configuring an absorption system that processes one or more vapor streams from a solvent extraction process to use extracted oil as an absorption medium, the absorption medium can be refreshed more frequently than when using external mineral oil. For example, the extracted oil used as the absorption medium may only be passed through the absorption column a single time or a few times (e.g., ten or less, such as five or less) before being discharged for downstream processing and/or delivery. As a result, the absorption medium may be continuously refreshed with fresh extracted oil not having previously passed through the absorption column. This may help improve the efficiency of the absorption system and/or reduce the operating cost of the system.

[0009] In one example, a method of recovering solvent from exhaust gas is described. The method includes receiving exhaust gas from one or more processing units in an extraction system in which oleaginous material is extracted with an organic solvent to produce vegetable oil and residual matter of reduced oil content, the exhaust gas comprising air mixed with an organic solvent. The method further includes absorbing at least a portion of the organic solvent from the exhaust gas in an absorption column using the vegetable oil produced by the extraction system as to absorb the organic solvent from the exhaust gas. In addition, the method includes vaporizing organic solvent absorbed by the vegetable oil to produce a recovered vegetable oil stream and a recovered solvent stream. In some applications of the example, at least a portion of the recovered vegetable oil stream is combined with vegetable oil produced by the extraction system downstream of the absorption column.

[0010] In another example, a method is described that includes extracting oleaginous material with an organic solvent to produce a miscella stream and a stream of solvent-wet residual solids in an extractor. The method includes vaporizing organic solvent from the miscella stream in a solvent recovery unit to produce an oil stream and a first recovered solvent stream and desolventizing the solvent-wet residual solids in a desolventizer to produce a dried residual solids stream and a second recovered solvent stream. The method further includes receiving exhaust gas containing organic solvent from at least the extractor and the desolventizer and passing the exhaust gas in a countercurrent direction through an absorption column with oil from the oil stream produced by the solvent recovery unit, thereby causing solvent to absorb from the exhaust gas into the oil. In addition, the method involves vaporizing organic solvent absorbed by the oil in a stripping column to produce a recovered oil stream and a third recovered solvent stream. The method also involves recombining at least a portion of the recovered oil stream with oil produced by the solvent recovery unit and having bypassed the absorption column.

[0011] In another example, an extractor system is described that includes an extractor, a solvent recovery unit, a desolventizer, an absorption unit, and a stripping column. The extractor is configured to receive a stream of oleaginous material to be processed and a stream of organic solvent and intermix the oleaginous material with the organic solvent within an extraction chamber thereby producing a miscella stream, a stream of solvent-wet residual solids, and a first exhaust gas comprising air mixed with organic solvent. The solvent recovery unit is configured to receive the miscella stream from the extractor and vaporize organic solvent from the miscella stream to produce an oil stream and a first recovered solvent stream. The desolventizer unit is configured to receive the solvent-wet residual solids from the extractor and produce a dried residual solids stream, a second recovered solvent stream, and a second exhaust gas comprising air mixed with organic solvent. The absorption column is configured to receive at least a portion of each of the first exhaust gas, the second exhaust gas, and the oil stream and intermix the first and second exhaust gases with the oil stream, thereby causing organic solvent to absorb from the first and second exhaust gases into the oil stream and produce an oil stream containing absorbed organic solvent. The stripping column is configured to receive the oil stream containing absorbed organic solvent from the absorption column and strip the organic solvent with steam to produce a recovered oil stream and a third recovered solvent stream.

[0012] The details of one or more examples are set forth in the accompanying drawings and the description below. Other features, objects, and advantages will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF DRAWINGS

[0013] FIG. 1 is a block diagram illustrating an example extraction system according to the disclosure.

[0014] FIG. 2 is a block diagram illustrating an example absorption system that can be used in conjunction with the example extraction system of FIG. 1.

DETAILED DESCRIPTION

[0015] In general, this disclosure relates to liquid-solid extractor systems and processes, including solvent recovery systems and processes. In some examples, an oleaginous material is processed in a continuous flow extractor that conveys a continuous flow of material from its inlet to its outlet while an organic solvent is conveyed in a countercurrent direction from a solvent inlet to a solvent outlet. As the solvent is conveyed from its inlet to its outlet, the concentration of extracted oil relative to solvent increases from a relatively small extract-to-solvent ratio to a comparatively large extract-to-solvent ratio. Similarly, as the solid material is conveyed in the opposing direction, the concentration of extract in the solid feedstock decreases from a comparatively high concentration at the inlet to a comparatively low concentration at the outlet. The amount of time the solid material remains in contact with the solvent within the extractor (which may also be referred to as residence time) can vary, for example depending on the material being processed and the operating characteristics of the extractor, although will typically be within the range of 15 minutes to 3 hours, such as from 1 hour to 2 hours.

[0016] The organic solvent discharged from the extractor, which may be referred to as a miscella, contains extracted oil from the oleaginous feedstock. The residual solid material discharged from the extractor contains solvent-wet solids having a reduced concentration of oil as compared to the original oleaginous feedstock. The miscella can be processed in a solvent recovery unit to vaporize the organic solvent from the extracted oil. The residual solid material can be processed in a desolventizer unit to vaporize the organic solvent from the solid material. Vapor stream(s) from the solvent recovery unit and/or desolventizer unit may be condensed to remove condensed water and/or organic solvent, producing an exhaust gas stream containing air and residual organic solvent.

[0017] In some examples of the present disclosure, the exhaust gas stream can be processed in an absorption column that receives a portion of the extracted oil separated from the miscella stream at the solvent recovering unit. Organic solvent in the exhaust gas steam can absorb into the extracted oil, producing a substantially solvent-free exhaust gas stream. The extracted oil used to absorb organic solvent from the exhaust gas may be stripped with steam to provide a recovered extracted oil stream and recovered solvent stream.

[0018] FIG. 1 is a block diagram illustrating an example extraction system 10 according to the disclosure. System 10 includes an extractor 12, a solvent recovery unit 14, and a desolventizer unit 16. In operation, a feedstock 18 containing a material to be extracted is introduced into a feed inlet of the extractor 12 and solvent 20 is introduced into a solvent inlet of the extractor. The feedstock 18 is contacted with the solvent 20 within the extractor 12 to extract oil from the feedstock into the solvent. The extractor can produce a miscella stream 22 containing extracted oil in organic solvent. The extractor can also produce a solvent wet residual solids stream 24 containing residual solid material from the feedstock whose oil content has been extracted.

[0019] In the example configuration of system 10, the miscella stream 22 is conveyed to solvent recovery unit 14. The miscella stream 22 can be processed within the solvent recovery unit to separate extracted oil from the organic solvent. For example, solvent recovery unit 14 may receive steam that vaporizes solvent from the miscella stream 22. Solvent recovery unit 14 can produce an extracted oil stream 26 substantially or entirely devoid of organic solvent and a first recovered solvent stream 28. Organic solvent within the first recovered solvent stream 28 may be mixed with air and/or steam. In some examples, the first recovered solvent stream 28 is passed through a condenser to remove condensable liquids, including recovered solvent, yielding a residual stream of non-condensable exhaust gas. This first exhaust gas may contain residual and/or entrained organic solvent that does not condense within the condenser.

[0020] Solvent-wet solids stream 24 in the example configuration of FIG. 1 is conveyed to the desolventizer unit 16. The desolventizer unit 16 can dry the solvent wet solids discharged from extractor 12. For example, desolventizer unit 16 may apply heat either directly or indirectly to the solvent wet solids, such as forced air and/or steam, to vaporize solvent from the surface of the solids. The desolventizer unit 16 can produce a dried residual solids stream 30 and second recovered solvent stream 32. The second recovered solvent stream 32 may be passed through a condenser to remove condensable liquids, including recovered solvent from the solvent wet solids, yielding a residual stream of non-condensable exhaust gas. The second exhaust gas may contain residual and/or entrained organic solvent that does not condense within the condenser.

[0021] Extractor 12 can be implemented using any suitable type of extractor configuration. In different examples, extractor 12 may be an immersion extractor, a percolation extractor, or yet other type of extractor design. Independent of the specific configuration of extractor 12, the extractor may be configured to operate so the feedstock stream 18 and solvent stream 20 flow in countercurrent directions through a housing of the extractor. For example, fresh oil-bearing feedstock 18 may flow through one inlet of the extractor housing while fresh solvent substantially or entirely devoid of extracted oil is passed through a second inlet of the extractor. As solvent travels through the extractor housing from the solvent inlet to the miscella outlet, the solvent can flow in a countercurrent direction to the flow of solid material passing from the feedstock inlet to the residual solids outlet. The solvent can intermix with the oil-bearing material within the extractor, causing oil and/or other extractable components to extract out of the solid feedstock into the solvent. The concentration of extract (e.g., oil) relative to solvent increases from a relatively small extract-to-solvent ratio to a comparatively large extract-to-solvent ratio. Similarly, as the solid feedstock is conveyed in the opposing direction, the concentration of extract in the solid feedstock decreases from a comparatively high concentration at the inlet to a comparatively low concentration at the outlet.

[0022] Extractor 12 can process any desired oleaginous feedstock using any suitable extraction fluid. Example types of oleaginous materials that can be processed using extractor 12 include, but are not limited to, soybeans (and/or soy protein concentrate), rapeseed, sunflower seed, peanuts, cottonseed, palm kernels, and corn germ and combinations thereof, as well as other oil-bearing seeds and fruits. Solvents that can be used to extract oil contained within the oleaginous material being processed are generally organic solvents, such as acetone, hexane, and/or toluene. Typical oleaginous materials processed using extractor 12 are plant-based materials, yielding a triglyceride vegetable oil as an extracted oil product.

[0023] Solvent recovery unit 14 processing miscella stream 22 to separate extracted oil from solvent can be implemented using one or more separation units. For example, solvent recovery unit 14 may be implemented using one or more distillation columns, stripping columns, and/or evaporator units. Independent of the specific configuration of solvent recovery unit 14, the solvent recovery unit may be effective to remove substantially all of the organic solvent from the extracted oil in the miscella stream 22. For example, solvent recovery unit 14 may produce extracted oil stream 26 having less than 5 weight percent organic solvent, such as less than 3 weight percent organic solvent, less than 1 weight percent organic solvent, or less than 0.5 weight percent organic solvent.

[0024] Desolventizer unit 16 processing residual solids stream 24 can also be implemented using one or more separation units. For example, desolventizer unit 16 may be configured as a desolventizer toaster or other desolventizing device that increases the temperature the solids stream 24. The temperature of the stream may be increased to a temperature above the boiling point of the solvent introduced into extractor 12, causing residual solvent to vaporize. In some configurations, steam is injected into desolventizer unit 16 in addition to or in lieu of any other direct or indirect heating.

[0025] In the example arrangement of FIG. 1, oil stream 26 recovered from the oleaginous feedstock 18 is sent to a storage reservoir 34 before further processing or downstream distribution. As will be discussed with respect to FIG. 2, at least a portion of oil stream 26 may be used to help process the exhaust gas streams produced elsewhere within system 10. For example, extracted oil may be conveyed directly from solvent recovery unit 14 and/or reservoir 34 to an absorption column used to process exhaust gases to remove residual organic solvent in the exhaust gases.

[0026] FIG. 2 is a block diagram illustrating an example absorption system 50 that can be used in conjunction with extraction system 10 from FIG 1. In the illustrated example, absorption system 50 includes an absorption column 52 and a stripping column 54. Although the example configuration shows only a single absorption column and a single stripping column, it should be appreciated that practical implementations of such a system may include one or more absorption columns 52 and/or one or more stripping columns 54.

[0027] Absorption column 52 can receive exhaust gases 56 containing residual organic solvent from one or more processing units of extraction system 10. For example, absorption column 52 may receive exhaust gas from solvent recovery unit 14, desolventizer unit 16, and/or any other processing unit within the extraction system generating exhaust gas. Exhaust gas streams from different processing units may be combined together and processed as a single stream by absorption column 52, or separate exhaust gas streams from separate processing units may be processed on different absorption columns. Typically, exhaust gas delivered to absorption column 52 will have first been passed through a condenser to remove condensable gases and/or liquids from the gas stream. As a result, the exhaust gas being processed by the absorption column may be cooled, non-condensable gas.

[0028] To remove residual organic solvent from the exhaust gas stream 56, extracted oil produced by extraction system 10 may be used as an absorption medium that is introduced into absorption column 52. For example, extracted oil from solvent recovery unit 14 and/or reservoir 34 may be used as an oil absorption stream 58 that is introduced into absorption column 52. Within the absorption column 52, organic solvent contained in exhaust gas 56 can transfer from the gas phase to the liquid phase. In different configurations, the exhaust gas 56 and oil absorption medium 58 can travel in a co-current direction through absorption column 52, a countercurrent direction through the column, or a cross-current direction. In one configuration, exhaust gas 56 enters a vertical absorption column 52 at or adjacent the bottom of the column and the oil absorption medium 58 enters at or adjacent the top of the column. The exhaust gas and oil absorption medium travel in countercurrent directions through the absorption column 52, producing an exit gas 60 in an exit liquid 62.

[0029] Absorption of organic solvent from the gas phase to the liquid phase in absorption column 52 may be effective to remove a sufficient amount of organic solvent to allow exit gas 60 to be discharged to atmosphere. In some examples, substantially all of the organic solvent in the gas phase is absorbed into the liquid phase within absorption column 52. For example, exhaust gas 56 entering absorption column 52 may have from 30 weight percent to 70 weight percent organic solvent. By contrast, after being contacted with extracted oil from extraction system 10 within absorption column 52, exit gas 60 may have less than 5 weight percent organic solvent. The concentration of organic solvent in the extracted oil introduced as the absorption medium 58 into absorption column 52 may range 0 weight percent to 5 weight percent, such as from 0 weight percent to 2 weight percent. The concentration of organic solvent in the exit liquid 62 may increase to a range from 1 weight percent to 15 weight percent, such as from 3 weight percent to 15 weight percent, or from 5 weight percent to 10 weight percent. In this way, the residual organic solvent in the exhaust gas can be removed for further processing.

[0030] Absorption column 52 can have a variety of different configurations. In some examples, absorption column 52 includes one or more packed beds along with corresponding support plates and liquid distribution hardware to cause the exhaust gas and extracted oil absorption liquid to intermix. In other examples, however, absorption column 52 may be configured as a trayed column which may or may not have one or more packed beds sections as well. In a trayed column configuration, absorption column 52 can include a plurality of trays vertically spaced from one another. Each tray may have openings that allow the passage of gas from one tray to an adjacent tray and a downcomer that directs the flow of liquid from one tray to an adjacent tray. For example, each tray may be configured as a valve tray with movable or fixed valves. A fixed valve tray configuration may be useful to provide good contact between the rising exhaust gas and falling oil used as the absorption medium while helping to minimize performance degradation due to fouling and other service life issues.

[0031] After exhaust gas 56 has passed through absorption column 52, the resulting exit gas 60 may be discharged to atmosphere or directed to other suitable downstream processing. The oil absorption medium containing organic solvent absorbed from the exhaust gas stream 62 can be processed in stripping column 54 to remove the absorbed organic solvent. In some configurations, stripping gas such as steam 64 is introduced into the stripping column 54 to strip the organic solvent from the oil absorption medium. Accordingly, stripping column 54 may produce a recovered oil stream 66 substantially or entirely devoid of organic solvent absorbed from the exhaust gas stream. Stripping column 54 may also produce a third recovered solvent stream 68 containing solvent vapor intermixed with stripping gas that can then be sent to a condenser for condensing and further processing. Although not illustrated, an oil heater and/or other processing equipment may process the exit liquid 62 from absorption column 52 before entering stripping column 54.

[0032] Because absorption system 50 utilizes extracted oil from extraction system 10 as the absorption medium, the absorption system may be readily replenished with fresh oil absorption medium during operation. In some configurations, extracted oil stream 26 produced by extraction system 10 is split with a portion of the stream directed to absorption system 50 (thereby forming stream 58) with a remainder of the stream sent downstream, such as to reservoir 34 or other downstream processing vessel. In other configurations, the entire extracted oil stream 26 is sent to reservoir 34 or other downstream processing vessel and the extracted oil absorption medium used in absorption system 50 is drawn downstream in the process. In some examples, the downstream vessel is or includes a drying vessel, e.g., that removes water from the oil.

[0033] For example, extracted oil stream 26 or a portion thereof may be degummed, refined, or otherwise processed in one or more downstream processing units from extractor 10 and solvent recovery unit 14. The oil used as the absorption medium in absorption system 50 may be drawn after such degumming, refining, and/or other processing, which may reduce the fouling tendency of the oil in absorption column 52.

[0034] Recovered oil stream 66 following stripping may be recycled within absorption system 50 and used again as the oil absorption medium 58 for absorption column 52. Alternatively, recovered oil stream 66 or a portion thereof may be discharged from absorption system 50. For example, recovered oil stream 66 may be returned to reservoir 34 or other processing location from where the oil was originally extracted, causing the oil stream to be combined with other extracted and/or processed oil that did not pass through absorption system 50. For example, recovered oil may be recombined with oil that did not pass through absorption system 50 downstream of the absorption column. The recovered oil and bypass oil may be recombined at or upstream of a drying vessel in which the combined stream is subsequently processed, e.g., to remove moisture from the combined stream.

[0035] While oil may be used for multiple passes through absorption column 52, in some applications, the oil is only passed through absorption column 52 a single pass before being discharged from absorption system 50. The recovered oil following the single pass through absorption column 52 may be recombined with extracted oil produced by extraction system 10 and not having gone through absorption column 52, e.g., downstream of where the extracted oil is withdrawn for use in absorption system 50. This one-pass arrangement may improve absorption efficiency, reduce oil degradation, and reduce fouling as compared to recycling the absorption oil through the absorption column for many passes.

[0036] Various examples have been described. These and other examples are within the scope of the following claims.

CLAIMS:

1. A method of recovering solvent from exhaust gas comprising:

receiving exhaust gas from one or more processing units in an extraction system in which oleaginous material is extracted with an organic solvent to produce vegetable oil and residual matter of reduced oil content, the exhaust gas comprising air mixed with an organic solvent;

absorbing at least a portion of the organic solvent from the exhaust gas in an absorption column using the vegetable oil produced by the extraction system to absorb the organic solvent from the exhaust gas;

vaporizing organic solvent absorbed by the vegetable oil to produce a recovered vegetable oil stream and a recovered solvent stream; and

recombining at least a portion of the recovered vegetable oil stream with vegetable oil produced by the extraction system downstream of the absorption column.

2. The method of claim 1, wherein vaporizing organic solvent absorbed by the vegetable oil comprises delivering vegetable oil having absorbed organic solvent from the absorption column to a stripping column and stripping the organic solvent from the vegetable oil with a vapor stream.

3. The method of claim 2, wherein the vapor stream comprises steam.

4. The method of claim 2, wherein the stripping column comprises a plurality of trays vertically spaced from each other having openings that allow the passage of gas from one tray to an adjacent tray.

5. The method of claim 4, wherein the plurality of trays comprise valve trays.

6. The method of any one of the foregoing claims, wherein absorbing at least a portion of the organic solvent from the exhaust gas in the absorption column comprises conveying the vegetable oil and the exhaust gas in a countercurrent direction through the absorption column.

7. The method of any one of the foregoing claims, wherein the absorption column receives a stream of vegetable oil from a source and a stream of exhaust gas and discharges a processed exhaust gas stream substantially devoid of organic solvent and a stream of vegetable oil having absorbed organic solvent absorbed.

8. The method of any one of the foregoing claims, wherein:

the extraction system comprises an extractor in which the oleaginous material is contacted with the organic solvent to produce a miscella stream and a stream of solvent-wet residual solids and a solvent recovery unit that receives the miscella stream and vaporizes organic solvent from the miscella stream to produce a vegetable oil stream and a recovered organic solvent stream, and

the absorption column receives the vegetable oil used to absorb the organic solvent from the exhaust gas from the solvent recovery unit.

9. The method of claim 8, wherein the solvent recovery unit comprises at least one of a distillation column, a stripping column, and an evaporator.

10. The method of any one of the foregoing claims, wherein:

the vegetable oil stream is split between the absorption column and a downstream vessel, and

the recovered vegetable oil stream following vaporization of the organic solvent is combined at the downstream vessel with vegetable oil split to the downstream vessel without having passed through the absorption column.

11. The method of claim 10, wherein the recovered vegetable oil stream is further processed in a drying vessel prior to being combined at the downstream vessel with vegetable oil split to the downstream vessel without having passed through the absorption column.

12. The method of claim 10, wherein the downstream vessel is a drying vessel.

13. The method of any one of the foregoing claims, wherein the absorption column receives vegetable oil that has not previously passed through the absorption column during operation such that vegetable oil used to absorb the organic solvent from the exhaust gas is only passed through the absorption column a single pass.

14. The method of any one of the foregoing claims, wherein the vegetable oil is at least one of degummed and refined prior to be received by the absorption column.

15. The method of any one of the foregoing claims, wherein processing units in the extraction system include at least an extractor and a desolventizer that desolventizes solvent-wet residual solids discharged from the extractor, and the absorption column receives exhaust gas from at least the extractor and desolventizer.

16. The method of any one of the foregoing claims, further comprising condensing the organic solvent in the exhaust gas prior to passing the exhaust gas through the absorption column.

17. The method of any one of the foregoing claims, wherein the organic solvent is hexane.

18. The method of any one of the foregoing claims, wherein the oleaginous material is selected from the group consisting of soybeans, rapeseed, peanuts, sunflower seed, cottonseed, palm kernels, corn germ, and combinations thereof.

19. A method comprising:

extracting oleaginous material with an organic solvent to produce a miscella stream and a stream of solvent-wet residual solids in an extractor;

vaporizing organic solvent from the miscella stream in a solvent recovery unit to produce an oil stream and a first recovered solvent stream;

desolventizing the solvent-wet residual solids in a desolventizer to produce a dried residual solids stream and a second recovered solvent stream;

receiving exhaust gas comprising organic solvent from at least the extractor and the desolventizer and passing the exhaust gas in a countercurrent direction through an absorption column with oil from the oil stream produced by the solvent recovery unit, thereby causing solvent to absorb from the exhaust gas into the oil;

vaporizing organic solvent absorbed by the oil in a stripping column to produce a recovered oil stream and a third recovered solvent stream; and recombining at least a portion of the recovered oil stream with oil produced by the solvent recovery unit and having bypassed the absorption column.

20. The method of claim 19, wherein the stripping column comprises a plurality of trays vertically spaced from each other having openings that allow the passage of gas from one tray to an adjacent tray.

21. The method of claim 20, wherein the plurality of trays comprise valve trays.

22. The method of any one of claims 19–21, wherein the solvent recovery unit comprises at least one of a distillation column, a stripping column, and an evaporator.

23. The method of any one of claims 19–22, wherein:

the oil stream is split following the solvent recovery unit between the absorption column and a downstream vessel, and

the recovered oil stream following vaporization of the organic solvent is combined at the downstream vessel with oil split to the downstream vessel without having passed through the absorption column.

24. The method of claim 23, wherein the recovered oil stream is further processed in a drying vessel prior to being combined at the downstream vessel with oil split to the downstream vessel without having passed through the absorption column.

25. The method of claim 23, wherein the downstream vessel is a drying vessel.

26. The method of any one of claims 19–25, wherein the absorption column receives oil that has not previously passed through the absorption column during operation such that oil used to absorb the organic solvent from the exhaust gas is only passed through the absorption column a single pass.

27. The method of any one of claims 19–26, wherein the organic solvent is hexane.

28. The method of any one of claims 19–27, wherein the oleaginous material is selected from the group consisting of soybeans, rapeseed, sunflower seed, cottonseed, palm kernels, corn germ, and combinations thereof.

29. An extractor system comprising:

an extractor configured to receive a stream of oleaginous material to be processed and a stream of organic solvent and intermix the oleaginous material with the organic solvent within an extraction chamber thereby producing a miscella stream, a stream of solvent-wet residual solids, and a first exhaust gas comprising air mixed with organic solvent;

a solvent recovery unit configured to receive the miscella stream from the extractor and vaporize organic solvent from the miscella stream to produce an oil stream and a first recovered solvent stream;

a desolventizer unit configured to receive the solvent-wet residual solids from the extractor and produce a dried residual solids stream, a second recovered solvent stream, and a second exhaust gas comprising air mixed with organic solvent;

an absorption column configured to receive at least a portion of each of the first exhaust gas, the second exhaust gas, and the oil stream and intermix the first and second exhaust gases with the oil stream, thereby causing organic solvent to absorb from the first and second exhaust gases into the oil stream and produce an oil stream containing absorbed organic solvent; and

a stripping column configured to receive the oil stream containing absorbed organic solvent from the absorption column and strip the organic solvent with steam to produce a recovered oil stream and a third recovered solvent stream.

30. The system of claim 29, wherein the stripping column comprises a plurality of trays vertically spaced from each other having openings that allow the passage of gas from one tray to an adjacent tray.

31. The system of claim 30, wherein the plurality of trays comprise valve trays.

32. The system of any one of claims 29–31, wherein the absorption column is configured to convey the first and second exhaust gas in a countercurrent direction with the oil stream.

33. The system of any one of claims 29–32, wherein the extractor comprises one of a continuous immersion extractor and a continuous percolation extractor.

34. The system of any one of claims 29–33, wherein the solvent recovery unit comprises at least one of a distillation column, a stripping column, and an evaporator.

35. The system of any one of claims 29–34, wherein the desolventizer comprises a desolventizer-toaster.

36. The system of any one of claims 29–35, wherein:

the oil stream is split between the absorption column and a downstream vessel, and

the recovered oil stream following the stripping column is combined at the downstream vessel with oil split to the downstream vessel without having passed through the absorption column.

37. The system of claim 36, wherein the recovered oil stream is further processed in a drying vessel prior to being combined at the downstream vessel with oil split to the downstream vessel without having passed through the absorption column.

38. The system of claim 36, wherein the downstream vessel is a drying vessel.

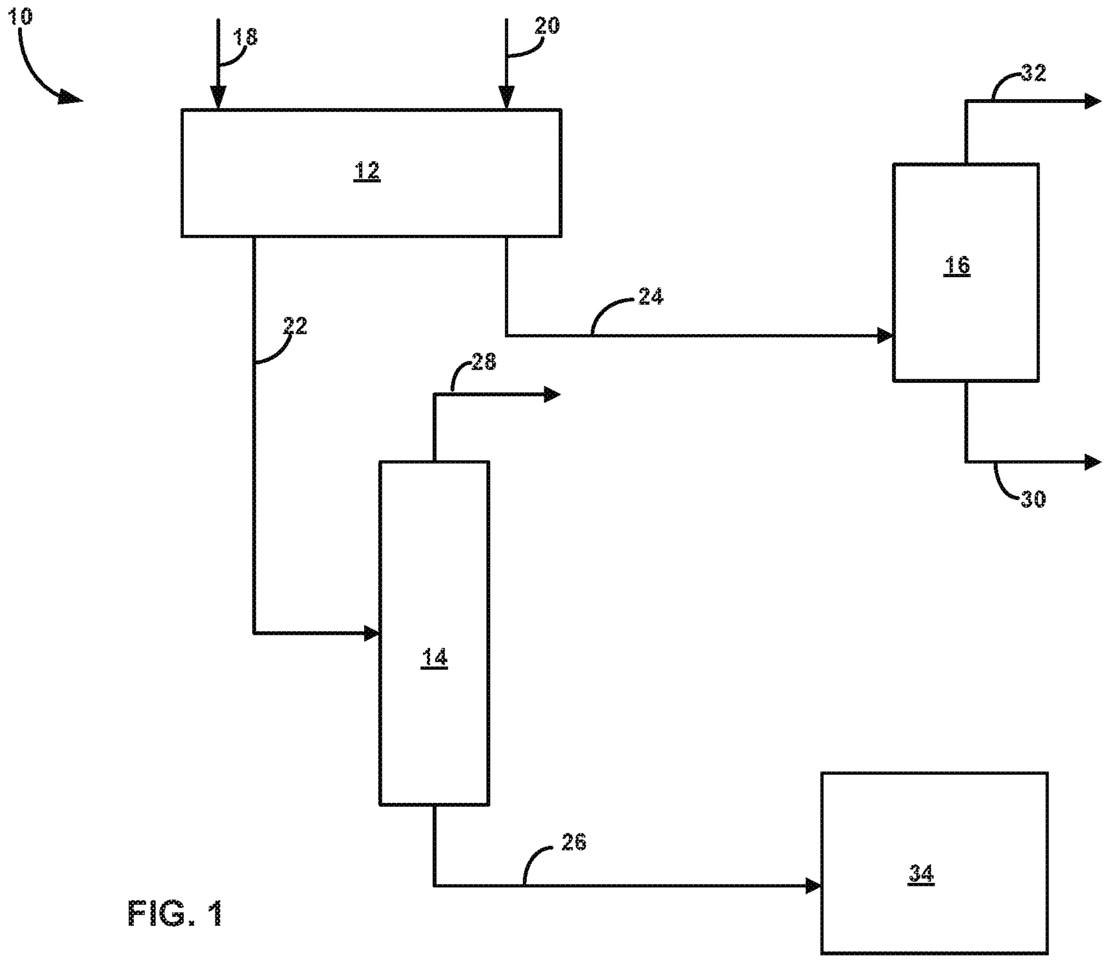

FIG. 1

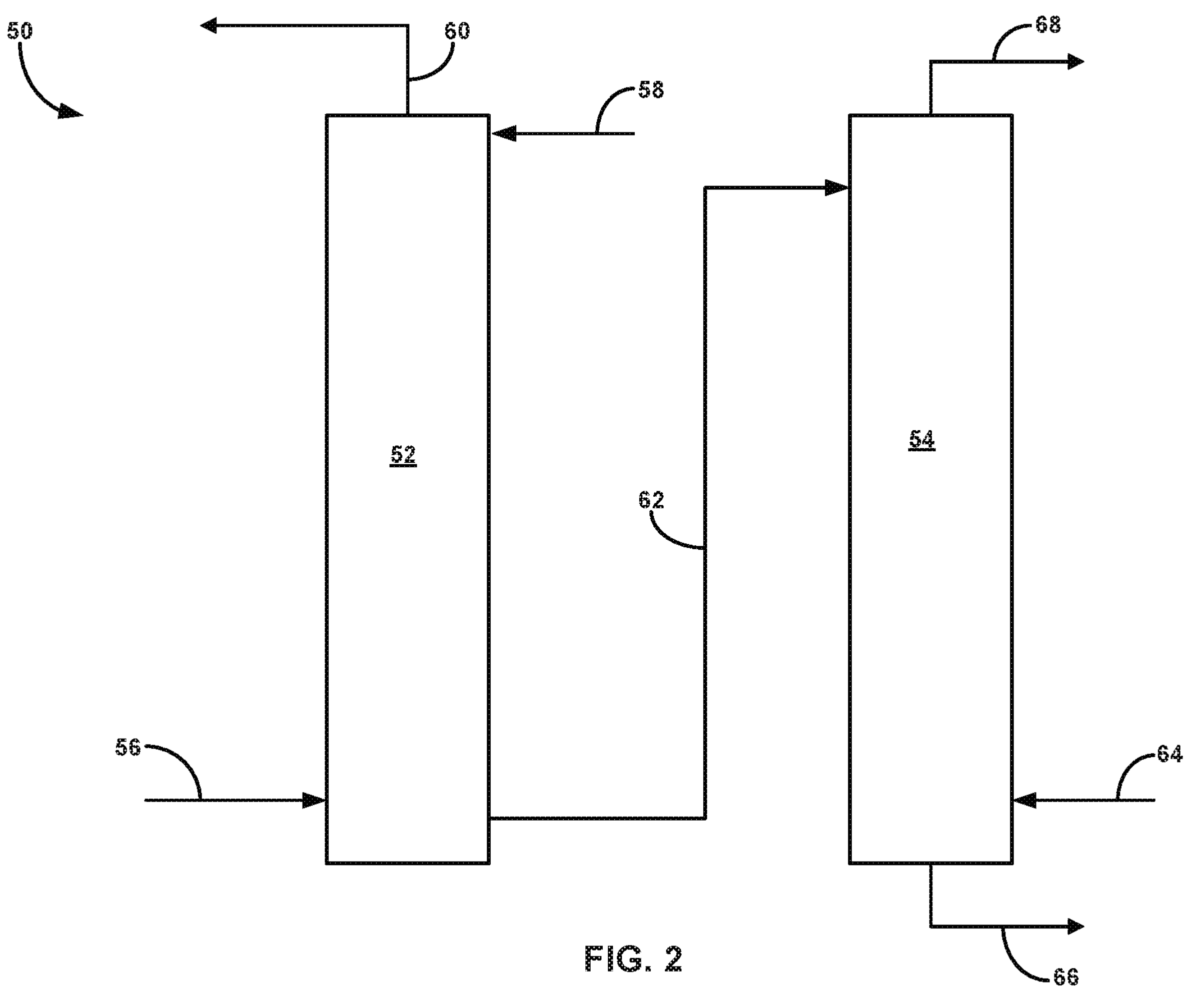

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 18/64211

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - B01D 53/78, F01N 3/20 (2019.01)
CPC - B01D 2251/70, B01D 2257/404, B01D 2257/502

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)
See Search History Document

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X -- Y	RIZVI "Separation, extraction and concentration processes in the food, beverage and nutraceutical industries" 2010. Retrieved online from https://books.google.com/books?id=13ZwAgAAQBAJ&pg=PA422&lpg#v=onepage&q&f=false ON 02 March 2019 (02.03.2019); Page 2 para[0003]; Page 3 para[0002]-[0003], [0005]-[0007]; Page 4 para[0001]-[0002];	1-4, 6/(1-4) --------------- 5, 6/5, 19-22, 29-32
Y	US 3966982 A (BECKER et al.) 29 June 1976 (29.06.1976) Abstract, Col 4 lines 63-66; Col 5 lines 10-12, 22-36; Claim 10;	19-22, 29-32
Y	US 5120474 A (BINKLEY et al.) 09 June 1992 (09.06.1992) Title, Col 2 lines 32-38; Col 4 lines 34-47, 64-68; Col 5 lines 1-5;	5, 6/5, 21, 22/21, 31, 32/31
A	WIKIPEDIA "Countercurrent exchange" 30 March 2017 (30.03.2017) Retrieved from https://en.wikipedia.org/w/index.php?title=Countercurrent_exchange&oldid=772931932 on 02 March 2019 (02.03.2019); Page 1 para[0001]-[0002];	6, 19-22, 32
A	US 2003/0134018 A1 (TURNER et al.) 17 July 2003 (17.07.2003) Entire document	1-6, 19-22, 29-32
A	US 5620728 A (LANGLEY et al.) 15 April 1997 (15.04.1997) Entire document	1-6, 19-22, 29-32

☐ 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 application or patent 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
02 March 2019	22 MAR 2019

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 18/64211

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: 7-18, 23-28, 33-38
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.