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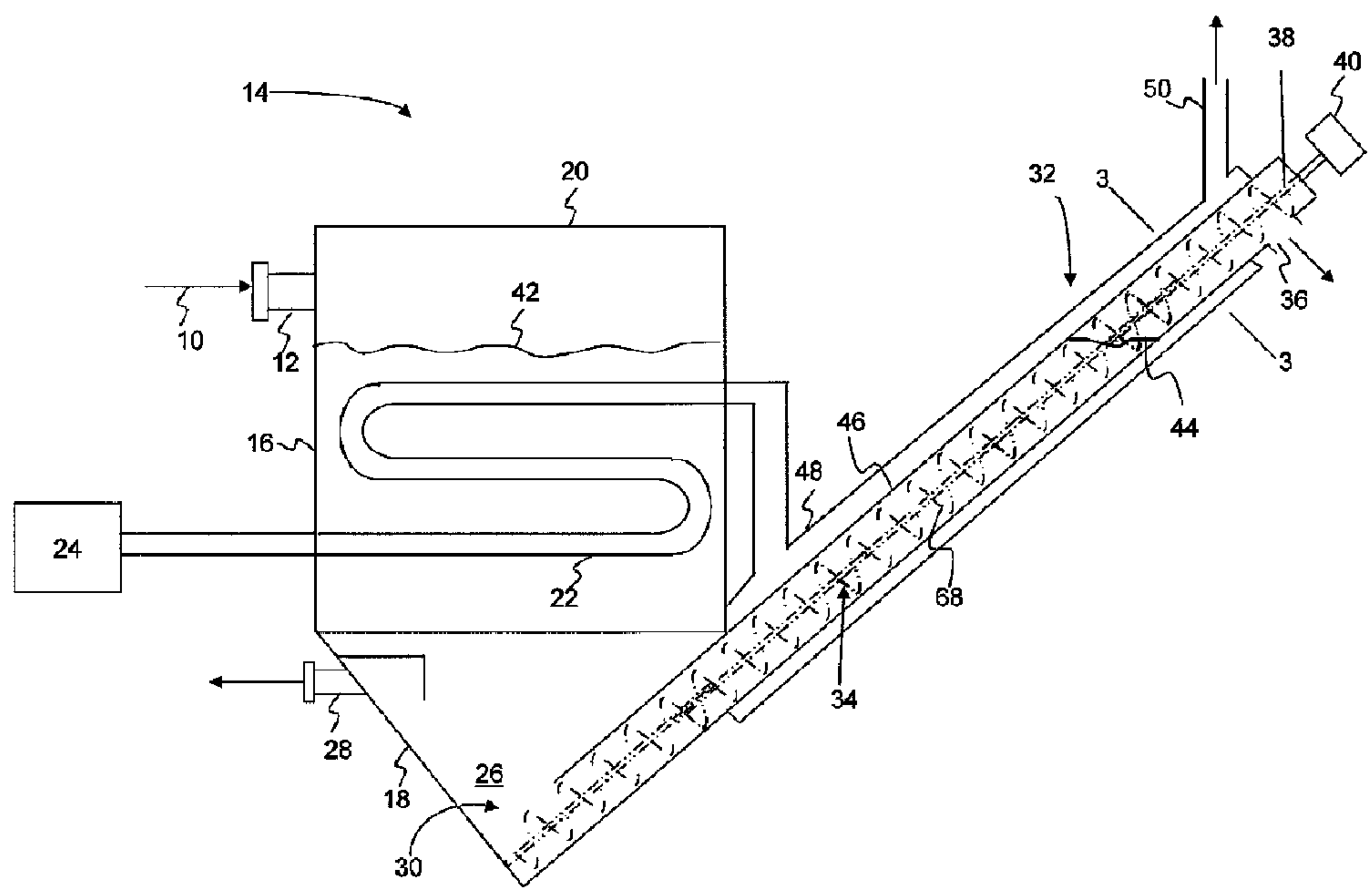

(57) Abrégé/Abstract:
A method for processing hydrocarbons recovered from a subterranean formation is disclosed. The method includes: feeding a stream including water, sand, and heavy hydrocarbons produced from a subterranean formation to a separation vessel; concurrently in the separation vessel: heating the stream components to an elevated temperature to reduce a viscosity of the heavy hydrocarbons; and separating the sand, the heavy hydrocarbon, and the water to form a water fraction, a hydrocarbon fraction, and a sand fraction comprising sand and at least one of water and heavy hydrocarbons; and recovering the water fraction from the separation vessel; recovering the hydrocarbon fraction from the separation vessel; and withdrawing the sand fraction from the separation vessel. Also disclosed are apparatus suitable for performing the above described method.

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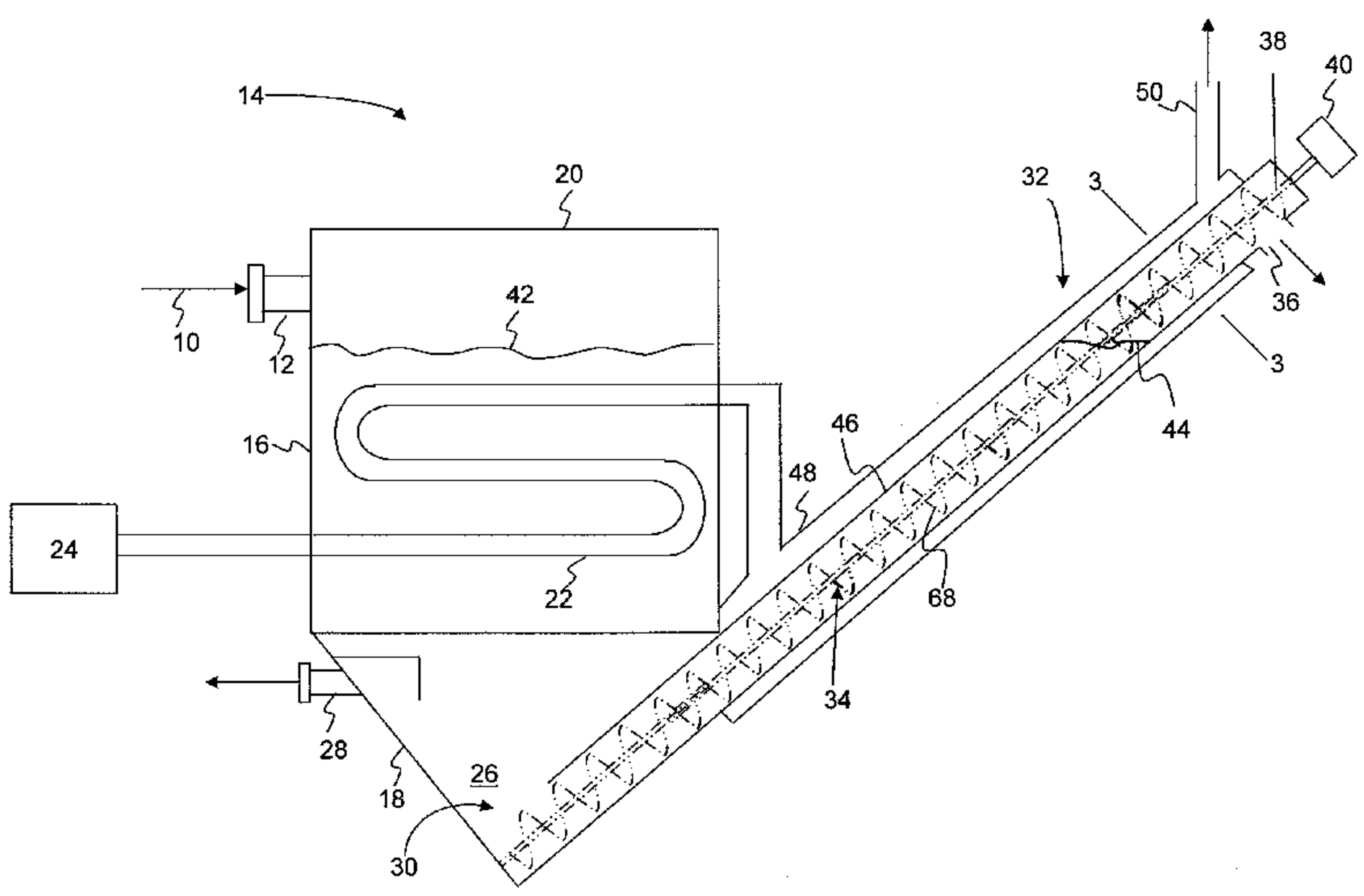
(54) **Title**: SAND DECANTER

Figure 1



(57) **Abstract**: A method for processing hydrocarbons recovered from a subterranean formation is disclosed. The method includes: feeding a stream including water, sand, and heavy hydrocarbons produced from a subterranean formation to a separation vessel; concurrently in the separation vessel: heating the stream components to an elevated temperature to reduce a viscosity of the heavy hydrocarbons; and separating the sand, the heavy hydrocarbon, and the water to form a water fraction, a hydrocarbon fraction, and a sand fraction comprising sand and at least one of water and heavy hydrocarbons; and recovering the water fraction from the separation vessel; recovering the hydrocarbon fraction from the separation vessel; and withdrawing the sand fraction from the separation vessel. Also disclosed are apparatus suitable for performing the above described method.

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SAND DECANTER

BACKGROUND OF DISCLOSURE

Field of the Disclosure

[0001] Embodiments disclosed herein relate generally to processing hydrocarbons recovered from a subterranean formation. More specifically, embodiments disclosed herein relate to processing heavy hydrocarbons, such as viscous oils, oil shale, tar sands, and other heavy hydrocarbons.

Background

[0002] Large deposits of heavy hydrocarbons (e.g., heavy oil and/or tar) contained in relatively permeable formations (e.g., in tar sands) are found in North America, South America, Africa, and Asia. Tar can be surface-mined and upgraded to lighter hydrocarbons such as crude oil, naphtha, kerosene, and/or gas oil. Surface milling processes may further separate the bitumen from sand. The separated bitumen may be converted to light hydrocarbons using conventional refinery methods. Mining and upgrading tar sand is usually substantially more expensive than producing lighter hydrocarbons from conventional oil reservoirs.

[0003] In situ production of hydrocarbons from tar sand may be accomplished by heating and/or injecting a gas into the formation. U.S. Patent Nos. 5,211,230 and 5,339,897, for example, describe a horizontal production well located in an oil-bearing reservoir. A vertical conduit may be used to inject an oxidant gas into the reservoir for in situ combustion. U.S. Patent No. 7,431,076 describes several additional processes for the production of heavy hydrocarbons.

[0004] Due to the high viscosity of heavy hydrocarbons, natural production rates are low, and the total volume of reservoir that can be economically drained with one wellbore is than that with less viscous oils. Indeed, in the case of bitumen, the oil often cannot be produced without thermal stimulation or solvent injection.

[0005] In some cases, a relatively permeable formation may be predominantly heavy hydrocarbons and/or tar with no supporting mineral grain framework and only floating (or no) mineral matter (e.g., asphalt lakes).

[0006] The relatively permeable formations may also include heavy hydrocarbons entrained in, for example, sand or carbonate. A tar sands formation, for example, is a formation in which hydrocarbons are predominantly present in the form of heavy hydrocarbons and/or tar entrained in a mineral grain framework or other host lithology (e.g., sand or carbonate).

[0007] The high viscosity of the heavy hydrocarbons may result in co-production of sand or carbonate when recovering the heavy hydrocarbons from a well or a mine. Produced heavy hydrocarbons, as a result, generally include a combination of clay, sand, water, and bitumen or other heavy hydrocarbons.

[0008] The co-produced solid materials, such as sand, must be separated from the heavy hydrocarbons before the hydrocarbons are further processed or upgraded. One such process is to feed the co-produced mixture to a settling vessel, wherein the mixture is heated, decreasing the viscosity of a portion of the hydrocarbons. The lower viscosity hydrocarbons float to the top of the settling vessel and are recovered, and the sand and a portion of the heavy hydrocarbons settle to the bottom of the vessel and are allowed to accumulate. The sands, having solidified in the bottom of the settling vessel, must then be periodically hydroblasted to regain the settling volume for further production. Depending upon well production rates, a production site using this hydrocarbon recovery technique may require several settling vessels, where service is continually rotated allowing for production and cleaning cycles. Further, the sand recovered from the settling vessels during cleaning contains a significant amount of hydrocarbons, requiring the sands to be disposed of in hazardous waste sites or otherwise processed before disposal. This type of separation process thus incurs a very large operating expense.

[0009] Accordingly, there exists a need for improved processes for the separation of heavy hydrocarbons from co-produced sand.

SUMMARY OF THE DISCLOSURE

[0010] In one aspect, embodiments disclosed herein relate to a method for processing hydrocarbons recovered from a subterranean formation, including: feeding a stream comprising water, sand, and heavy hydrocarbons produced from a subterranean formation to a separation vessel; concurrently in the separation vessel: heating the stream components to an elevated temperature to reduce a viscosity of the heavy hydrocarbons; and separating the sand, the heavy hydrocarbon, and the water to form a water fraction, a hydrocarbon fraction, and a sand fraction comprising sand and at least one of water and heavy hydrocarbons; and recovering the water fraction from the separation vessel; recovering the hydrocarbon fraction from the separation vessel; and withdrawing the sand fraction from the separation vessel.

[0011] In another aspect, embodiments disclosed herein relate to a system for processing hydrocarbons recovered from a subterranean formation, including: a separation vessel comprising: a vertical portion on top of an angled portion; at least one inlet nozzle for feeding a stream comprising water, sand, and heavy hydrocarbons produced from a subterranean formation into the vessel for separation into a hydrocarbon fraction, a water fraction, and a sand fraction comprising sand and at least one of water and heavy hydrocarbons; an indirect heat exchange device disposed within at least one of the vertical portion and the angled portion for heating the water, sand, and heavy hydrocarbons; at least one outlet nozzle for recovering the hydrocarbon fraction; at least one outlet nozzle for recovering the water fraction; a screw conveyor located at a bottom of the angled portion to concurrently transport the sand fraction from the bottom of the angled portion to a screw conveyor outlet and separate the sand fraction from at least a portion of the at least one of water and heavy hydrocarbons; and at least one outlet for recovering the sand fraction from the screw conveyor.

[0011a] In another aspect, embodiments disclosed herein relate to a method for processing hydrocarbons recovered from a subterranean formation, comprising: feeding a stream comprising water, sand, and heavy hydrocarbons produced from a subterranean formation to a separation vessel; concurrently in the separation vessel: heating the stream components to an elevated temperature to reduce a viscosity of the heavy hydrocarbons; and separating the sand, the heavy hydrocarbon, and the water to form a water fraction, a hydrocarbon fraction, and a sand fraction comprising sand and at least one of water and heavy hydrocarbons; and recovering the water fraction from the separation vessel; recovering the hydrocarbon fraction from the separation vessel; withdrawing the sand fraction from the separation vessel; and washing the sand fraction to recover at least a portion of any residual hydrocarbons.

[0011b] In another aspect, embodiments disclosed herein relate to a system for processing hydrocarbons recovered from a subterranean formation, comprising: a separation vessel comprising: a vertical portion on top of an angled portion; at least one inlet nozzle for feeding a stream comprising water, sand, and heavy hydrocarbons produced from a subterranean formation into the vessel for separation into a hydrocarbon fraction, a water fraction, and a sand fraction comprising sand and at least one of water and heavy hydrocarbons; an indirect heat exchange device disposed within at least one of the vertical portion and the angled portion for heating the water, sand, and heavy hydrocarbons; at least one outlet nozzle for recovering the hydrocarbon fraction; at least one outlet nozzle for recovering the water fraction; a screw conveyor located at a bottom of the angled portion to concurrently transport the sand fraction from the bottom of the angled portion to a screw conveyor outlet and separate the sand fraction from at least a portion of the at least one of water and heavy hydrocarbons; at least one outlet for recovering the sand fraction from the screw conveyor; and a sand wash system for washing the sand fraction to recover at least a portion of any residual hydrocarbons.

[0011c] In another aspect, embodiments disclosed herein relate to a method for processing hydrocarbons recovered from a subterranean formation, comprising: feeding a stream comprising water, sand, and heavy hydrocarbons produced from a subterranean formation through at least one inlet nozzle of a separation vessel; concurrently in the separation vessel: heating the stream components to an elevated temperature to reduce a viscosity of the heavy hydrocarbons; and separating the sand, the heavy hydrocarbon, and the water to form a water fraction, a hydrocarbon fraction, and a sand fraction comprising sand and at least one of water and heavy hydrocarbons, wherein the separating comprises: feeding the sand fraction to a screw conveyor including an inclined housing, a helical auger, an elevated pan disposed in and extending at least a portion of a length of the housing and having an arcuate cross section with a radius greater than a radius of the helical auger, wherein the pan is disposed proximate at least a lower quadrant of the helical auger, and a liquid recovery zone adjacent to the pan; transporting the sand fraction from an inlet of the inclined housing to an outlet of the inclined housing via the helical augur; separating the sand fraction from at least a portion of the at least one of water and heavy hydrocarbons; transporting the separated at least one of water and heavy hydrocarbons via the liquid recovery zone to a liquid collection zone; recovering the water fraction from the separation vessel; recovering the hydrocarbon fraction from the separation vessel; and withdrawing the sand fraction from the separation vessel.

[0011d] In another aspect, embodiments disclosed herein relate to a system for processing hydrocarbons recovered from a subterranean formation, comprising: a separation vessel comprising: a vertical portion on top of an angled portion; at least one inlet nozzle for feeding a stream comprising water, sand, and heavy hydrocarbons produced from a subterranean formation into the vessel for separation into a hydrocarbon fraction, a water fraction, and a sand fraction comprising sand and at least one of water and heavy hydrocarbons; an indirect heat exchange device disposed within at least one of the vertical portion and the angled portion for heating the water, sand, and heavy hydrocarbons; at least one outlet nozzle for recovering the hydrocarbon fraction; at least one outlet nozzle for recovering the water fraction; a screw conveyor located at a bottom of the angled portion to concurrently transport the sand fraction from the bottom of the angled portion to a screw conveyor outlet and separate the sand fraction from at least a portion of the at least one of water and heavy hydrocarbons; wherein the screw conveyor comprises a drying auger unit comprising: a. an inclined housing having side walls joined by a bottom and having an inlet end and an outlet end; b. at least one inlet fluidly connected to the bottom of the angled portion for feeding the sand fraction comprising sand and at least one of water and heavy hydrocarbons to the inlet end; c. a helical auger located in the housing for transporting the sand fraction from the inlet end of the housing to the outlet end of the housing, and a drive for rotating the auger, d. an elevated pan disposed in and extending at least a portion of the length of the housing and having an arcuate cross section with a radius greater than a radius of the helical auger, wherein the pan is disposed proximate at least a lower quadrant of the helical auger; e. the housing further comprising a liquid recovery zone adjacent to the pan for transporting the at least one of water and heavy hydrocarbons, separated from the sand during transport along the pan by the helical auger, to a liquid collection zone; f. an outlet for recovering the at least one of water and heavy hydrocarbons from the liquid collection zone; and g. at least one outlet for recovering sand having a reduced content of the at least one of water and heavy hydrocarbons.

[0012] Other aspects and advantages will be apparent from the following description and the appended claims.

BRIEF DESCRIPTION OF DRAWINGS

[0013] Figure 1 is a schematic diagram of a sand decanter according to embodiments disclosed herein.

[0014] Figure 2 is a schematic diagram of a sand decanter according to embodiments disclosed herein.

[0015] Figure 3 is a schematic diagram of a helical auger useful in sand decanters according to embodiments disclosed herein.

DETAILED DESCRIPTION

[0016] In one aspect, embodiments disclosed herein relate to processing hydrocarbons recovered from a subterranean formation. More specifically, embodiments disclosed herein relate to processing heavy hydrocarbons, such as viscous oils, oil shale, tar sands, and other heavy hydrocarbons.

[0017] Production of heavy hydrocarbons from subterranean formations, as described above, typically results in the co-production of water and sand from the subterranean formation. Embodiments disclosed herein provide for apparatus and methods for the separation of the heavy hydrocarbons from the co-produced water and sand.

[0018] "Heavy hydrocarbons," as used herein, refers to viscous hydrocarbon fluids. Heavy hydrocarbons may include highly viscous hydrocarbon fluids such as heavy oil, tar, and/or asphalt. Heavy hydrocarbons may include carbon and hydrogen, as well as smaller concentrations of sulfur, oxygen, and nitrogen. Additional elements may also be present in heavy hydrocarbons in trace amounts. Heavy hydrocarbons may be classified by API gravity. Heavy hydrocarbons generally have an API gravity below about 20°C. Heavy oil, for example, generally has an API gravity of about 10-20°C, whereas tar generally has an API gravity below about 10°C. The viscosity of heavy hydrocarbons is generally greater than about 100 centipoise at 15°C. Heavy hydrocarbons may also include aromatics or other complex ring hydrocarbons.

[0019] Tar generally refers to a viscous hydrocarbon that generally has a viscosity greater than about 10,000 centipoise at 15°C. The specific gravity of tar generally is greater than 1. Tar may have an API gravity less than 10°C.

[0020] Certain types of formations that include heavy hydrocarbons may also be, but are not limited to, natural mineral waxes, or natural asphaltites. Natural mineral waxes typically occur in substantially tubular veins that may be several meters wide, several kilometers long, and hundreds of meters deep. Natural asphaltites include solid hydrocarbons of an aromatic composition and typically occur in large veins.

[0021] The above described heavy hydrocarbons may be produced from formations including various mineral matrices. "Sand," as used herein, refers to sedimentary rock, sands, silicilytes, clays, carbonates, and other media that may be co-produced with heavy hydrocarbons, such as heavy hydrocarbons co-produced with sand as a slurry.

[0022] As produced from a well, a produced fluid including water, sand, and heavy hydrocarbons may be fed to a sand decanter according to embodiments disclosed herein, in which the produced fluid is concurrently i) heated to an elevated temperature to reduce the viscosity of the heavy hydrocarbon and ii) separated to form a water fraction, a hydrocarbon fraction, and a sand fraction. The sand fraction recovered may also include water and/or hydrocarbons, due to immersion in the liquid phases present (the hydrocarbon and/or the water being separated). The water fraction, the hydrocarbon fraction, and the sand fraction may then be separately recovered from the sand decanter.

[0023] The water fraction and the hydrocarbon fraction may be withdrawn from the sand decanter via a liquid draw. The sand fraction may be withdrawn from the sand decanter via a helical auger or screw conveyor. For example, the sand fraction may be fed from a lower portion of the sand decanter to an inlet of a screw conveyor. In some embodiments, the screw conveyor may concurrently i) transport the sand fraction from the inlet of the screw conveyor to the outlet of the screw conveyor, and ii) separate the sand fraction from at least a portion of the water and/or hydrocarbons present.

[0024] Heating of the co-produced heavy hydrocarbons, water, and sand within the sand decanter may be performed via indirect heat exchange. Heat exchange may be performed using various heat exchange media, including steam/water, hot oil, and hot gases. In some embodiments, hot gases produced from a burner, such as a natural gas burner, may be used. Combustion fuels used to produce gases for use in heat exchange may also include, for example, a portion of the heavy hydrocarbons recovered from the sand decanter or other hydrocarbons that may be present in the fluid produced from the subterranean formation. In other embodiments, electrical heating coils may be used for the heating.

[0025] The particular choice of heat exchange medium may depend upon the availability of each at the production site. For example, high pressure steam or other heat exchange medium may not be readily available. Natural gas, however, is often a readily available fuel at most production sites, and may be used to perform the desired separations within the sand decanter.

[0026] The sand, water, and heavy hydrocarbons in the fluids produced from a well may be heated to an elevated temperature sufficient to reduce the viscosity of the heavy hydrocarbon to promote separation of the fractions by gravity. In some embodiments, the fluid produced from the subterranean formation may have a temperature of 25°C or less, such as about 15°C or less. Heating of the produced fluid may increase the temperature of the mixture to a temperature in the range from about 50°C to less than about 100°C, such as a temperature in the range from about 60°C to 90°C in some embodiments, and a temperature in the range from about 70°C to about 80°C in other embodiments. As produced, the heavy hydrocarbons may be of a sufficiently high viscosity such that it adheres to the sand. When heated, the lower viscosity of the heavy hydrocarbon allows the sand to settle out of solution, resulting in separation of the sand from the heavy hydrocarbon and the water. The lower viscosity of the hydrocarbon additionally facilitates separation of the hydrocarbon from any water present, resulting in the production of two or three phases within the sand decanter (water/hydrocarbon and sand or water, hydrocarbon, and sand, depending upon the quantity of water produced and the solubility of water within the hydrocarbon phase). The resulting phases, sand (solids), hydrocarbons, and/or water, may then be recovered from the sand decanter as described above.

[0027] Separation and recovery of the heavy hydrocarbons from the co-produced sand may be performed in a sand decanter as disclosed herein, one embodiment of which is illustrated in Figure 1. The produced fluid from the subterranean formation may be fed via flow line 10 to an inlet 12 of sand decanter 14. Sand decanter 14 may include a vertical portion 16 on top of an angled portion 18. Vertical portion 16 may be open to the atmosphere or may include a top 20, enclosing the vessel and allowing for insulation of the vessel top and retention of heat.

[0028] The co-produced fluids may be heated within the vessel via indirect heat exchange with a heat exchange medium passed through heating coils 22. In some embodiments, for example, when a burner 24 is used to combust a fuel, such as natural gas, to produce a flue gas used as a heat exchange medium, heating coils 22 may be referred to as a fire tube.

[0029] As the fluid is heated within sand decanter 14, the viscosity of the heavy hydrocarbons is reduced, allowing the sand to settle to a bottom portion 26 of sand decanter 14. The oil and/or water phases, essentially free of sand, may be recovered via one or more fluid outlets 28. A feed port 30 to a screw conveyor 32 may be provided to continuously or intermittently remove sand from bottom portion 26.

[0030] Screw conveyor 32 may include a helical auger 34, rotation of which may result in the transport of sand from feed port 30 toward screw conveyor outlet 36. Rotation of helical auger 34 may be performed, for example, via coupling of shaft 38 to a drive unit 40, including a motor. A liquid level 42 may result within screw conveyor 32, and may have a height similar to that of the fluid level 44 within sand decanter 14. Screw conveyor 32 may have a height extending above fluid levels 42, 44, allowing for the sand to be separated from at least a portion of the fluid, which may include water and/or hydrocarbons, during transport of the sand to outlet 36.

[0031] Subterranean formations co-producing heavy hydrocarbons and sand may be located in regions having sub-zero temperatures for at least a portion of the year. Due to fluids, including hydrocarbons and/or water, remaining with the sand during transport via screw conveyor 32, insulation of screw conveyor 32 or heating of the sand during transport within screw conveyor 32 may be required to ensure transportability of the sand when ambient conditions may result in an unacceptable increase in hydrocarbon viscosity or freezing of water, each of which may result in undesired buildup within screw conveyor 32 or blockage of outlet 36.

[0032] Heating of screw conveyor 32 may be performed using heat tracing (electrical or heat exchange tubing or jacketing for flow of a heat exchange medium) around at least a portion of an exterior surface 46 of screw conveyor 32. As illustrated in Figure 1, for example, the flue gas passed through fire tubes 22 may be fed to jacket 48 for heating of the contents in screw conveyor 32. The flue gas may then be recovered from jacket outlet 50 for exhaust to the atmosphere or for further processing. The exterior of sand decanter 14 may additionally be insulated or jacketed to promote efficient heat transfer (not illustrated).

[0033] Referring now to Figure 2, a schematic diagram of a sand decanter according to other embodiments herein is illustrated, where like numerals represent like parts. In this embodiment, a portion 32A of screw conveyor 32 may be positioned horizontally along the length of bottom portion 26 for transport of the sand fraction from sand decanter 14. Screw conveyor 32 may also include transverse portion 32B for concurrently transporting the sand and separating the sand from at least a portion of the hydrocarbons and/or water that may be present. The helical auger located in portions 32A and 32B may be coupled for use with a single drive unit 40 or may be rotated using separate drive units (not illustrated). Also in this embodiment, screw conveyor inlet 30 may extend the length of horizontal portion 32A.

[0034] As mentioned above, liquids, such as hydrocarbons, water, or both, may be initially conveyed with the sand by screw conveyor 32. The length of the screw conveyor between liquid level 44 and outlet 36 may be sufficient to only remove a portion of the water and/or hydrocarbons from the sand. Further, wetting of the surface area of the sand may result in carryover of a significant amount of fluids.

[0035] In some embodiments, screw conveyor 32 may be a drying auger unit, allowing for the concurrent transportation of the sand and separation of a greater portion of the water and/or hydrocarbons from the sand fraction. Separation of hydrocarbons and water from sand during transport may be facilitated as shown in Figure 3, which may be a cross-sectional view of a drying auger unit 60, such as taken from section 3-3 shown in Figure 1. A drying auger unit 60 according to embodiments disclosed may include an inclined housing 62 having side walls 64 joined by a bottom 66.

[0036] A sand fraction, including sand, water and/or hydrocarbons, may be fed to drying auger unit 60 as described above. A helical auger 34, located at least partially within housing 62, may be used to transport the sand from feed port 30 toward outlet 36. Helical auger 34 may include multiple flights 68.

[0037] An elevated pan 70 is disposed in and extends along at least a portion of the length of housing 62. Due to liquid head requirements, a drying auger unit 60 may be located only at an upper portion of screw conveyor 30. Elevated pan 70 may have an arcuate cross section with an effective radius R greater than a radius r of helical auger 34. For example, elevated pan 70 may have a general half-u shaped cross-section.

[0038] Elevated pan 70, for example, may be located proximate a lower quadrant of the helical auger 34, preferably along the lower quadrant proximate the upward rotation U of flights 68. In some embodiments, elevated pan 70 may extend at least 90°, such as from a lowermost portion P, in the direction of rotation U of helical auger 34.

[0039] As the sand is transported via the rotation of helical auger 34 from inlet end 30 toward outlet end 36, the sand gathers on elevated pan 70 due to the rotational forces and friction generated by rotation of flights 68, and is transported toward outlet end 36. Gravitational forces acting upon the sand and/or compression of the mixture along the length of the helical auger 34 separates at least a portion of the hydrocarbons and/or water from the sand. The separated water/hydrocarbons may then flow into liquid recovery zone 72 for collection in a liquid collection zone (not shown). A sand fraction, having a decreased amount of water/hydrocarbons, may then be recovered via outlet 36.

[0040] As mentioned above, compression may be used in conjunction with gravity to separate the drilling fluid from the drill cuttings. For example, flights 68 of helical auger 34 may be evenly spaced in some embodiments, thus using primarily gravitational forces to separate the drilling fluid. In other embodiments, flights 68 may have a decreasing spacing along the length of elevated pan 70, thus compressing the cuttings slurry as it traverses from inlet end 30 toward outlet end 36, facilitating additional separation of drilling fluid from the cuttings slurry. Additionally, although only one helical auger is illustrated, two or more augers may be used.

[0041] Hydrocarbon fractions recovered from sand decanters according to embodiments disclosed herein may be forwarded for storage, transport, or further processing, such as to convert the heavy hydrocarbons to lighter hydrocarbons, such as light hydrocarbons (C1 to C6 hydrocarbons, including olefins), gasoline range hydrocarbons (C6 to C10 hydrocarbons, for example), diesel range hydrocarbons, light cycle oils, and he like, as known to those skilled in the art.

[0042] A water fraction recovered from sand decanters according to embodiments disclosed herein may contain some hydrocarbons. Thus, water fractions recovered may be further processed to remove the hydrocarbons, resulting in a water fraction suitable for disposal or reuse within the production facilities.

[0043] The sand fraction recovered from sand decanters according to embodiments disclosed herein may contain some hydrocarbons, as mentioned above. For example, heavy hydrocarbons remaining with sand during settling, such as due to adhesion or insufficient increase of viscosity, may result in the sand being unsuitable for non-hazardous disposal.

[0044] Sand fractions recovered according to embodiments disclosed herein may be rendered suitable for non-hazardous disposal using a sand cleaning system, such as that disclosed in U.S. Provisional Patent Application Serial No. 61/014,262, filed on December 17, 2007 (and also published in WO2009/079286). The cleaning of the sand may result in recovery of additional hydrocarbons that may be further processed as described above. Sand, having been cleaned to meet various regulations for non-hazardous disposal, may then be landfilled, re-injected into a well, or otherwise used or disposed of, on site or at a remote facility.

[0045] As described above, embodiments disclosed herein provide for the separation and recovery of sand from heavy hydrocarbons, such as bitumen or other heavy hydrocarbons produced from a low-pressure well. Advantageously, embodiments disclosed herein may provide for concurrently heating the heavy hydrocarbons to reduce a viscosity thereof and separating of the heavy hydrocarbons from co-produced sand.

[0046] The separations performed using sand decanters according to embodiments disclosed herein may allow for the continuous separation of sand, in contrast to current processes. Due to the continuous or intermittent withdrawal of a sand fraction from the sand decanters, buildup of sand in the separation vessel is reduced, requiring less intensive maintenance and the associated costs. Further, continuous separations according to embodiments disclosed herein may reduce the number of separation vessels required to perform the separations.

[0047] While the disclosure includes a limited number of embodiments, those skilled in the art, having benefit of this disclosure, will appreciate that other embodiments may be devised which do not depart from the scope of the present disclosure. Accordingly, the scope should be limited only by the attached claims.

CLAIMS:

1. A method for processing hydrocarbons recovered from a subterranean formation, comprising:

feeding a stream comprising water, sand, and heavy hydrocarbons produced from a subterranean formation to a separation vessel;

concurrently in the separation vessel:

heating the stream components to an elevated temperature to reduce a viscosity of the heavy hydrocarbons; and

separating the sand, the heavy hydrocarbon, and the water to form a water fraction, a hydrocarbon fraction, and a sand fraction comprising sand and

at least one of water and heavy hydrocarbons; and

recovering the water fraction from the separation vessel;

recovering the hydrocarbon fraction from the separation vessel;

withdrawing the sand fraction from the separation vessel; and

washing the sand fraction to recover at least a portion of any residual hydrocarbons.

2. The method of claim 1, wherein the separating comprises separating the sand, the heavy hydrocarbon, and the water by a density separation technique;

wherein the withdrawing comprises:

feeding the sand fraction to a screw conveyor; and

concurrently in the screw conveyor:

transporting the sand fraction from a screw conveyor inlet to a screw conveyor outlet; and

separating the sand fraction from at least a portion of the at least one of water and heavy hydrocarbons; and

recovering the sand fraction from the screw conveyor outlet.

3. The method of claim 1, wherein the heating comprises:

combusting a fuel to form a flue gas; and

heating the stream components via indirect heat exchange with the flue gas.

4. The method of claim 3, further comprising:

heating the sand fraction during the withdrawing via indirect heat exchange with at least a portion of the flue gas.

5. The method of claim 3, wherein the fuel comprises at least one of a natural gas and a portion of the recovered hydrocarbon fraction.

6. The method of claim 1, further comprising at least one of reinjecting at least a portion of the washed sand into a subterranean formation and landfilling at least a portion of the washed sand.

7. The method of claim 1, wherein the separation vessel comprises:

a vertical portion on top of an angled portion;

at least one inlet nozzle for feeding a stream comprising water, sand, and heavy hydrocarbons produced from a subterranean formation into the vessel for separation into a hydrocarbon fraction, a water fraction, and a sand fraction comprising sand and at least one of water and heavy hydrocarbons;

an indirect heat exchange device disposed within at least one of the vertical portion and the angled portion for heating the water, sand, and heavy hydrocarbons;

at least one outlet nozzle for recovering the hydrocarbon fraction;

a screw conveyor located at a bottom of the angled portion to concurrently transport the sand fraction from the bottom of the angled portion to a screw conveyor outlet and separate the sand fraction from at least a portion of the at least one of water and heavy hydrocarbons.

8. The method of claim 7, wherein the separation vessel further comprises at least one outlet nozzle for recovering the water fraction.

9. The method of claim 7, wherein the screw conveyor comprises a drying auger unit comprising:

a. an inclined housing having side walls joined by a bottom and having an inlet end and an outlet end;

b. at least one inlet fluidly connected to the bottom of the angled portion for feeding the sand fraction comprising sand and at least one of water and heavy hydrocarbons to the inlet end;

c. a helical auger located in the housing for transporting the sand fraction from the inlet end of the housing to the outlet end of the housing, and a drive for rotating the auger,

d. an elevated pan disposed in and extending at least a portion of the length of the housing and having an arcuate cross section with a radius greater than a radius of the helical auger, wherein the pan is disposed proximate at least a lower quadrant of the helical auger;

e. the housing further comprising a liquid recovery zone adjacent to the pan for transporting the at least one of water and heavy hydrocarbons, separated from the sand during transport along the pan by the helical auger, to a liquid collection zone;

f. an outlet for recovering the at least one of water and heavy hydrocarbons from the liquid collection zone; and

g. at least one outlet for recovering sand having a reduced content of the at least one of water and heavy hydrocarbons.

10. A system for processing hydrocarbons recovered from a subterranean formation, comprising:

a separation vessel comprising:

a vertical portion on top of an angled portion;

at least one inlet nozzle for feeding a stream comprising water, sand, and heavy hydrocarbons produced from a subterranean formation into the vessel for separation into a hydrocarbon fraction, a water fraction, and a sand fraction comprising sand and at least one of water and heavy hydrocarbons;

an indirect heat exchange device disposed within at least one of the vertical portion and the angled portion for heating the water, sand, and heavy hydrocarbons;

at least one outlet nozzle for recovering the hydrocarbon fraction;

at least one outlet nozzle for recovering the water fraction;

a screw conveyor located at a bottom of the angled portion to concurrently transport the sand fraction from the bottom of the angled portion to a screw conveyor outlet and separate the sand fraction from at least a portion of the at least one of water and heavy hydrocarbons;

at least one outlet for recovering the sand fraction from the screw conveyor; and

a sand wash system for washing the sand fraction to recover at least a portion of any residual hydrocarbons.

11. The system of claim 10, further comprising an indirect heat exchange device disposed at an exterior of at least a portion of the screw conveyor for heating the sand fraction during transport.

12. The system of claim 10, further comprising a combustion system for combusting a fuel to produce a flue gas for use in indirect heat exchange in at least one of the indirect heat exchange device disposed within at least one of the vertical portion and the angled portion and the indirect heat exchange device disposed at an exterior of at least a portion of the screw conveyor.

13. The system of claim 10, wherein the screw conveyor comprises a drying auger unit comprising:

a. an inclined housing having side walls joined by a bottom and having an inlet end and an outlet end;

b. at least one inlet fluidly connected to the bottom of the angled portion for feeding the sand fraction comprising sand and at least one of water and heavy hydrocarbons to the inlet end;

c. a helical auger located in the housing for transporting the sand fraction from the inlet end of the housing to the outlet end of the housing, and a drive for rotating the auger,

d. an elevated pan disposed in and extending at least a portion of the length of the housing and having an arcuate cross section with a radius greater than a radius of the helical auger, wherein the pan is disposed proximate at least a lower quadrant of the helical auger;

e. the housing further comprising a liquid recovery zone adjacent to the pan for transporting the at least one of water and heavy hydrocarbons, separated from the sand during transport along the pan by the helical auger, to a liquid collection zone;

f. an outlet for recovering the at least one of water and heavy hydrocarbons from the liquid collection zone; and

g. at least one outlet for recovering sand having a reduced content of the at least one of water and heavy hydrocarbons.

14. A method for processing hydrocarbons recovered from a subterranean formation, comprising:

feeding a stream comprising water, sand, and heavy hydrocarbons produced from a subterranean formation through at least one inlet nozzle of a separation vessel;

concurrently in the separation vessel:

heating the stream components to an elevated temperature to reduce a viscosity of the heavy hydrocarbons; and

separating the sand, the heavy hydrocarbon, and the water to form a water fraction, a hydrocarbon fraction, and a sand fraction comprising sand and at least one of water and heavy hydrocarbons, wherein the separating comprises:

feeding the sand fraction to a screw conveyor including an inclined housing, a helical auger, an elevated pan disposed in and extending at least a portion of a length of the housing and having an arcuate cross section with a radius greater than a radius of the helical auger, wherein the pan is disposed proximate at least a lower quadrant of the helical auger, and a liquid recovery zone adjacent to the pan;

transporting the sand fraction from an inlet of the inclined housing to an outlet of the inclined housing via the helical augur;

separating the sand fraction from at least a portion of the at least one of water and heavy hydrocarbons;

transporting the separated at least one of water and heavy hydrocarbons via the liquid recovery zone to a liquid collection zone;

recovering the water fraction from the separation vessel;

recovering the hydrocarbon fraction from the separation vessel; and

withdrawing the sand fraction from the separation vessel.

15. A system for processing hydrocarbons recovered from a subterranean formation, comprising:

a separation vessel comprising:

a vertical portion on top of an angled portion;

at least one inlet nozzle for feeding a stream comprising water, sand, and heavy hydrocarbons produced from a subterranean formation into the vessel for separation into a hydrocarbon fraction, a water fraction, and a sand fraction comprising sand and at least one of water and heavy hydrocarbons;

an indirect heat exchange device disposed within at least one of the vertical portion and the angled portion for heating the water, sand, and heavy hydrocarbons;

at least one outlet nozzle for recovering the hydrocarbon fraction;

at least one outlet nozzle for recovering the water fraction;

a screw conveyor located at a bottom of the angled portion to concurrently transport the sand fraction from the bottom of the angled portion to a screw conveyor outlet and separate the sand fraction from at least a portion of the at least one of water and heavy hydrocarbons;

wherein the screw conveyor comprises a drying auger unit comprising:

a. an inclined housing having side walls joined by a bottom and having an inlet end and an outlet end;

b. at least one inlet fluidly connected to the bottom of the angled portion for feeding the sand fraction comprising sand and at least one of water and heavy hydrocarbons to the inlet end;

c. a helical auger located in the housing for transporting the sand fraction from the inlet end of the housing to the outlet end of the housing, and a drive for rotating the auger,

d. an elevated pan disposed in and extending at least a portion of the length of the housing and having an arcuate cross section with a radius greater than a radius of the helical auger, wherein the pan is disposed proximate at least a lower quadrant of the helical auger;

e. the housing further comprising a liquid recovery zone adjacent to the pan for transporting the at least one of water and heavy hydrocarbons, separated from the sand during transport along the pan by the helical auger, to a liquid collection zone;

f. an outlet for recovering the at least one of water and heavy hydrocarbons from the liquid collection zone; and

g. at least one outlet for recovering sand having a reduced content of the at least one of water and heavy hydrocarbons.

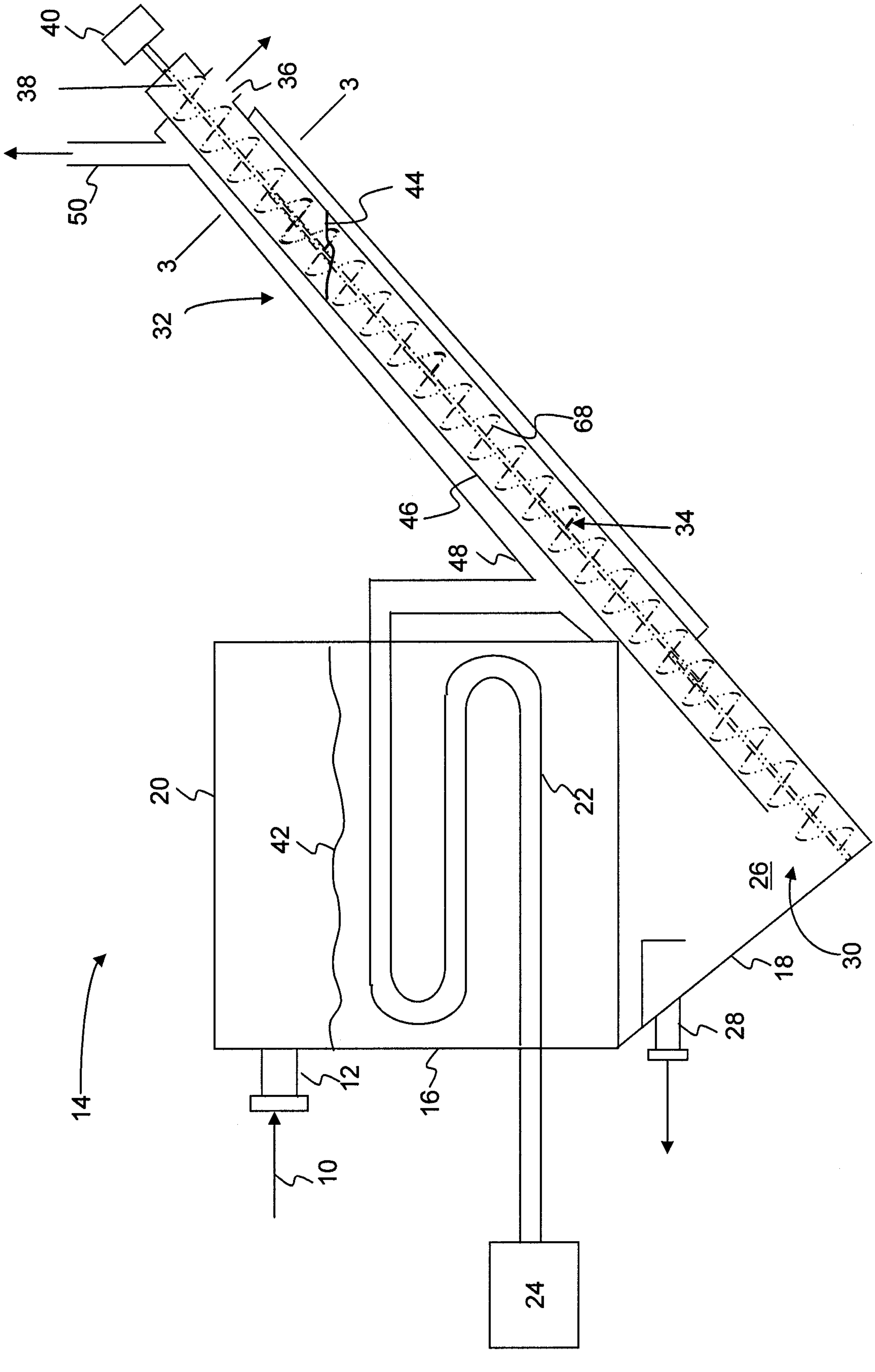


Figure 1

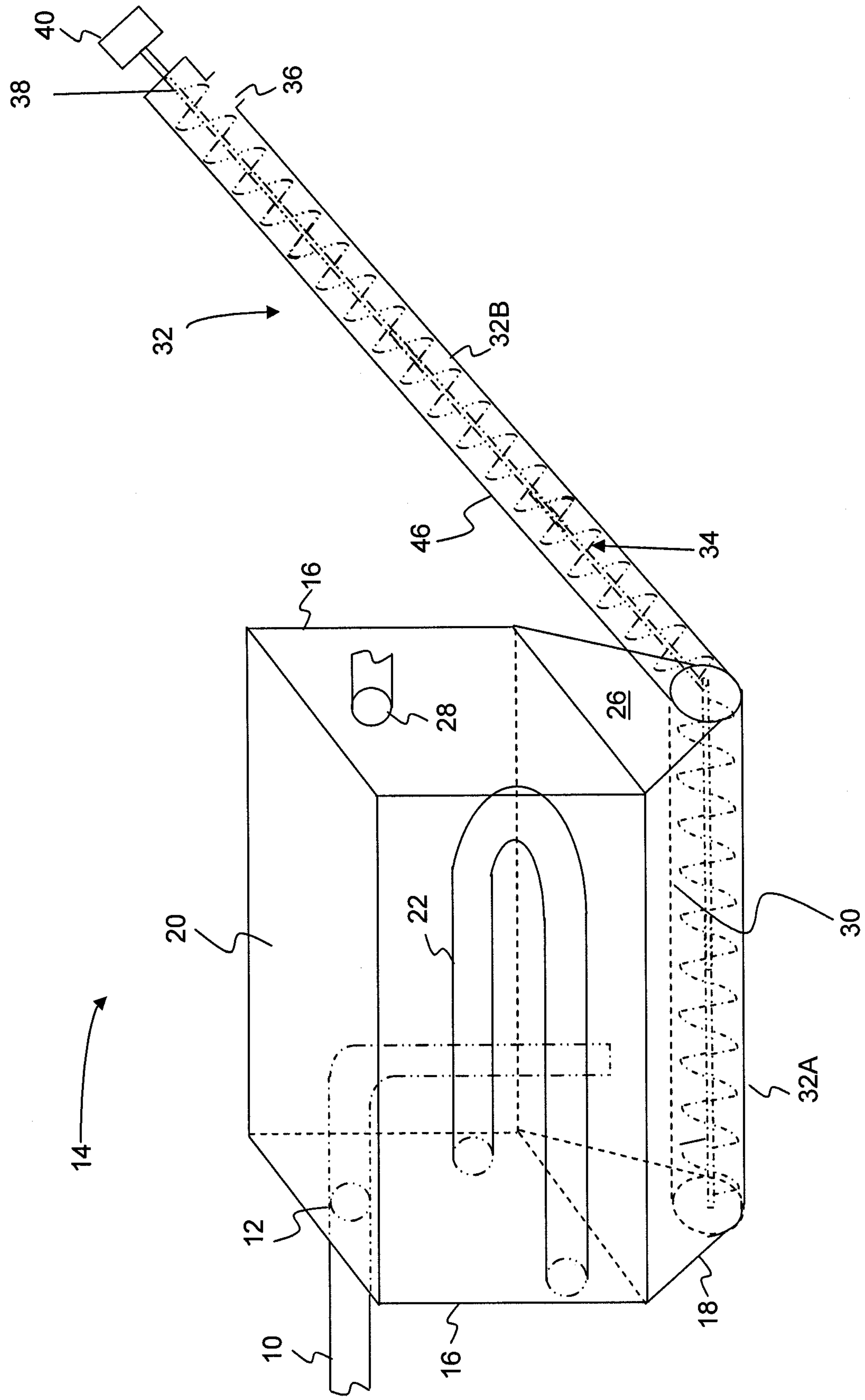
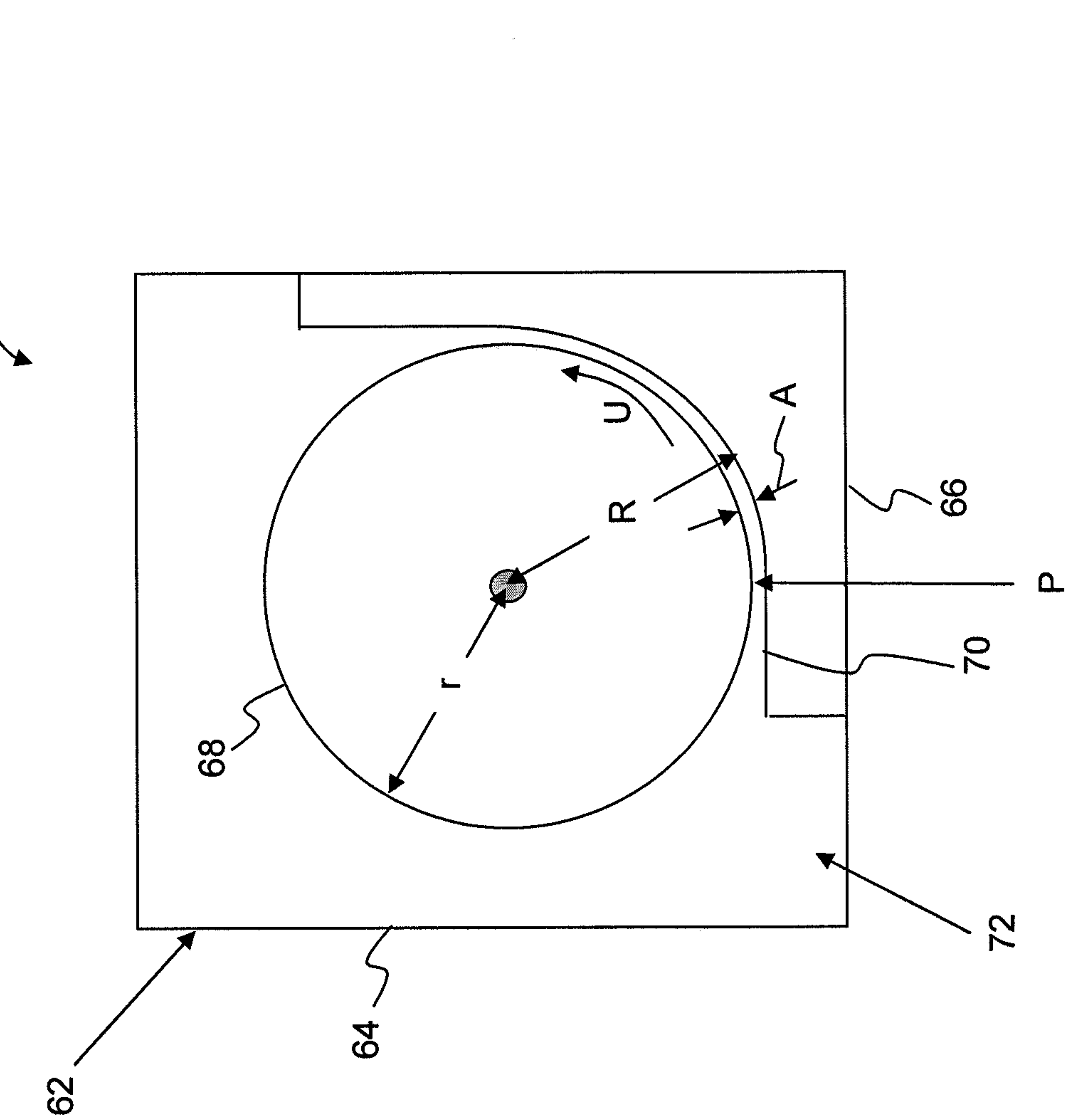
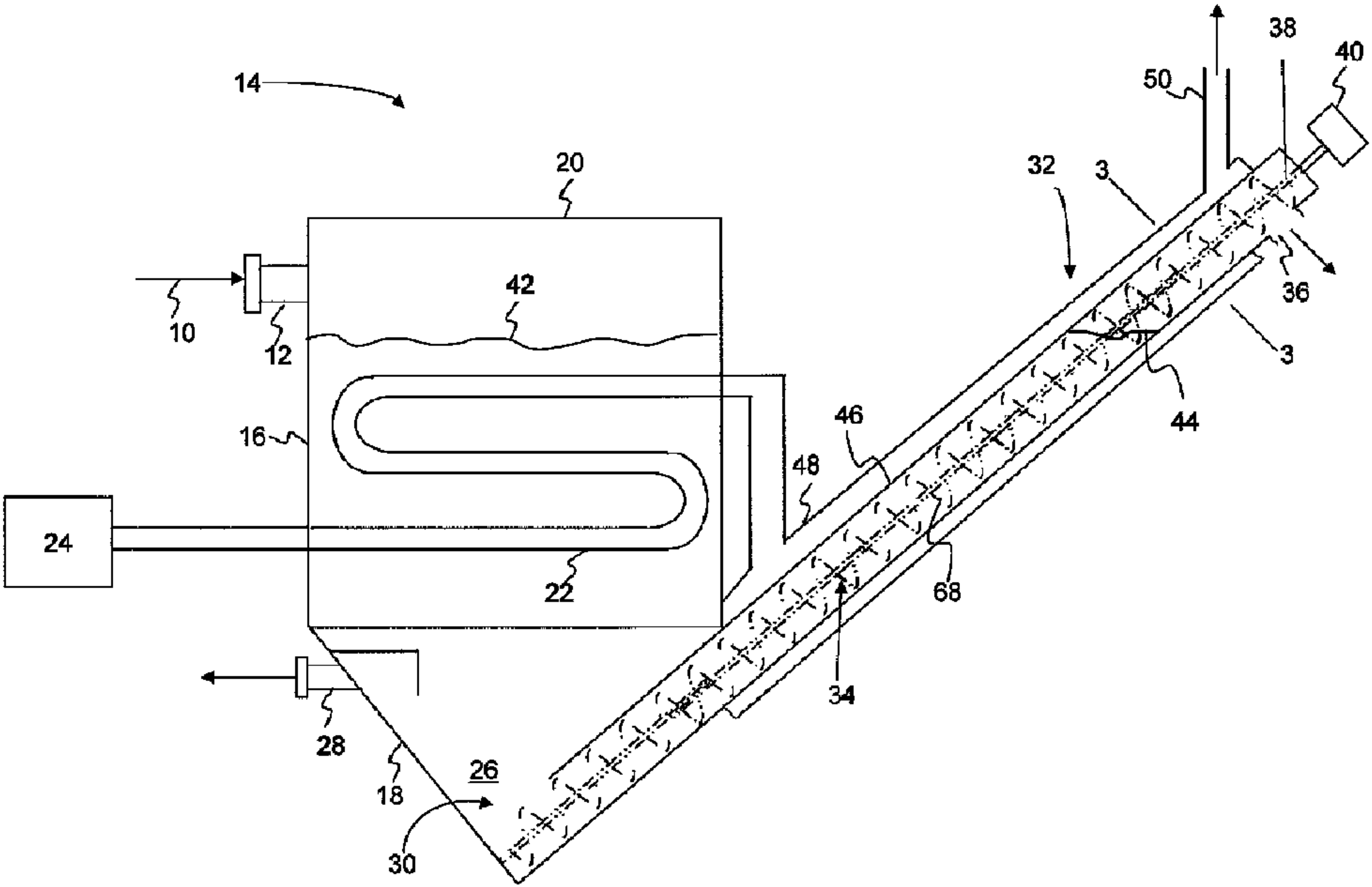


Figure 2

Figure 3





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