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(54) **METHOD FOR PROCESSING HEAVY
HYDROCARBON OIL**

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(57) **ABSTRACT**

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14, 2011.

A process for treating hydrocarbon oil including passing heated oil through a cavitation apparatus to statically induce cavitation treatment of the oil. The oil is passed through the cavitation apparatus in the absence on non-hydrocarbon oil substances such as hydrogen, water or other organic materials and solvents. The cavitation treatment process can increase the API gravity of the hydrocarbon oil and reduce the viscosity of the hydrocarbon oil.

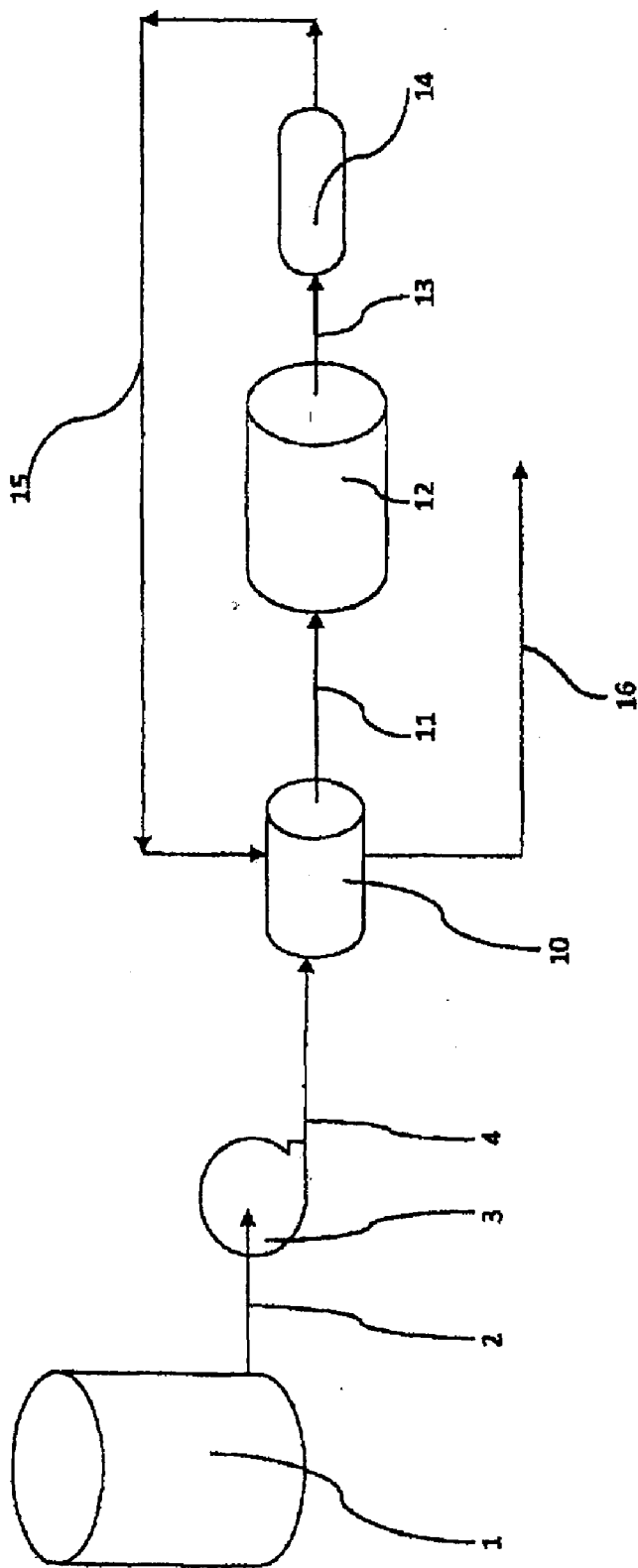


FIG.1

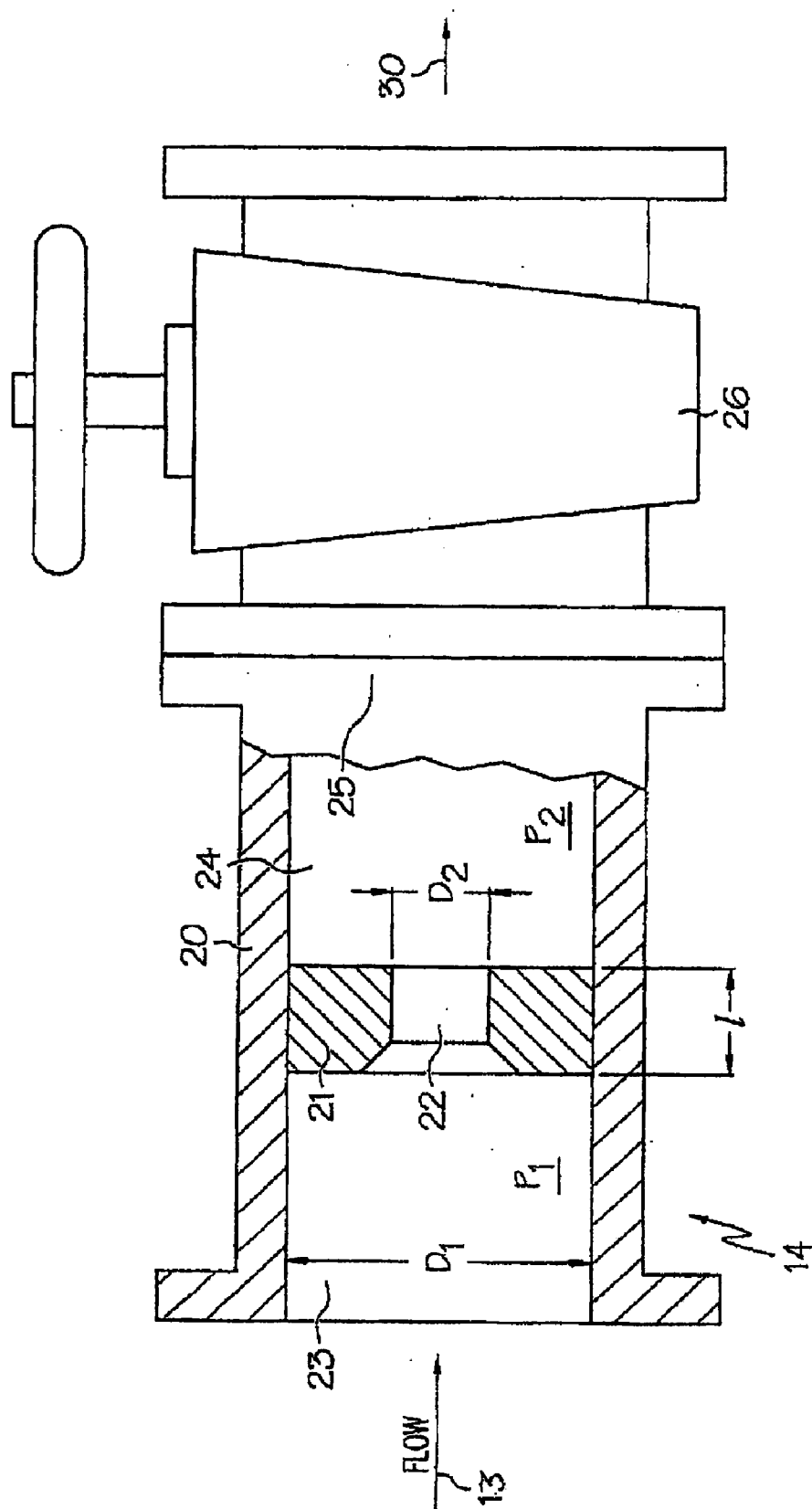


FIG. 2

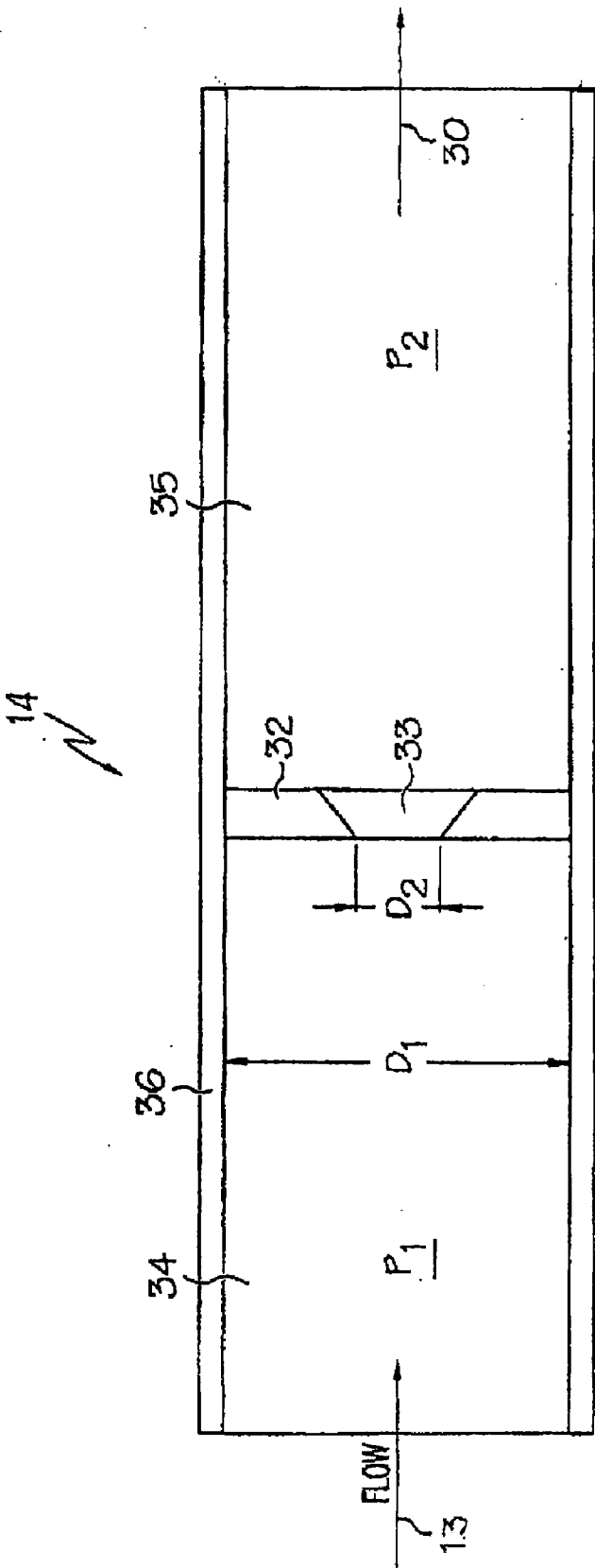


FIG.3

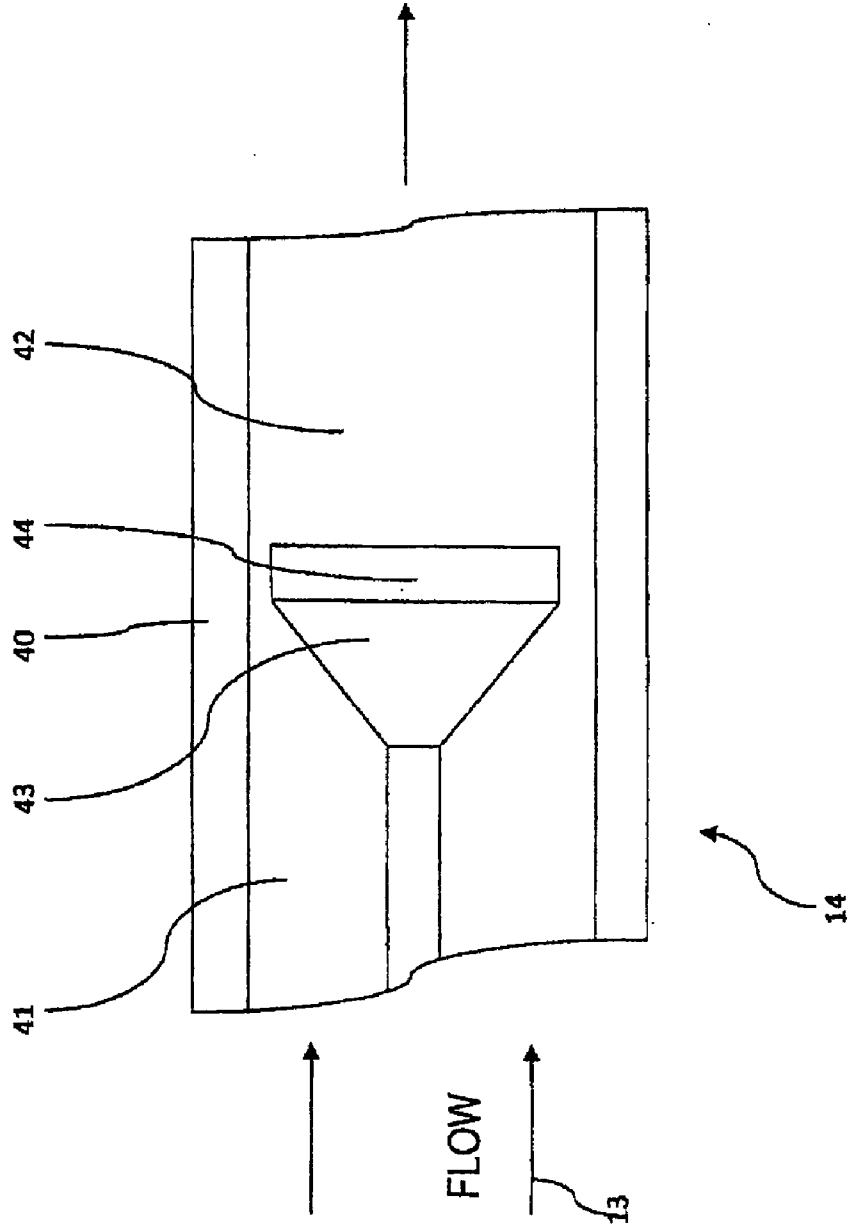


FIG. 4

METHOD FOR PROCESSING HEAVY HYDROCARBON OIL

[0001] This application claims the benefit of U.S. provisional application Ser. No. 61/534,507 filed Sep. 14, 2011, the contents of which are incorporated herein in their entirety by reference.

FIELD

[0002] The invention relates to methods of treating hydrocarbon oil and, more particularly, to methods for reducing the viscosity and increasing specific gravity of heavy hydrocarbon oil.

BACKGROUND

[0003] Oil reserves are gradually being depleted and costs related to processing heavy oil resources, for example oils having API gravity less than about 23, continue to increase. Large quantities of such heavy oils are available in oil deposits in Western Canada and heavy bituminous oils extracted from oil sands. Other sources of heavy oils can be such materials as atmospheric tar bottoms products, vacuum tar bottoms products, heavy cycle oils, shale oils, coal-derived liquids, crude oil residua, topped crude oils, and combinations thereof.

[0004] Efficient processing and viscosity reduction of heavy hydrocarbon oils is desirable for the production, transport and refining operations of crude oil. Commonly practiced methods include diluting the crude oil with gas condensate and emulsification with caustic and water, in addition to thermally treating crude oil and combining crude oil with hydrogen gas. Limitations or disadvantages of these methods can include long reaction times that result in an increase in the generation of undesirable waste materials, specifically pitch, coke, and olefins. These materials create significant disposal challenges for the processing facility, and, in addition, lead to a reduction in the efficiency of the facility. Thus, there is a need for novel technologies for treating heavy oils and bitumen to yield lighter and less viscous resources.

SUMMARY

[0005] A process for treating a hydrocarbon oil including providing a flow-through, hydrodynamic cavitation apparatus having a local constriction. The hydrocarbon oil is passed through the local constriction of the flow-through, hydrodynamic cavitation apparatus to form cavitation bubbles. No substances that are not a hydrocarbon oil are passed through the cavitation apparatus with the hydrocarbon oil, either in a mixture with the hydrocarbon oil or separately. The cavitation bubbles are collapsed under static pressure to treat the hydrocarbon oil. The treated hydrocarbon oil is extracted or removed from the cavitation apparatus. The treated hydrocarbon oil has an increased API gravity compared to the untreated hydrocarbon oil prior to passing it through the cavitation apparatus.

[0006] A process for treating a hydrocarbon oil including providing a flow-through, hydrodynamic cavitation apparatus having a local constriction. The hydrocarbon oil is passed through the local constriction of the flow-through, hydrodynamic cavitation apparatus to form cavitation bubbles. No substances that are not a hydrocarbon oil are passed through the cavitation apparatus with the hydrocarbon oil, either in a mixture with the hydrocarbon oil or separately. The cavitation bubbles are collapsed under static pressure to treat the hydrocarbon oil. The treated hydrocarbon oil is extracted or removed from the cavitation apparatus. The treated hydrocar-

bon oil has a reduced viscosity compared to the untreated hydrocarbon oil prior to passing it through the cavitation apparatus.

[0007] A process for reducing the viscosity of a heavy hydrocarbon oil including providing a flow-through, hydrodynamic cavitation apparatus having a local constriction. A preheated fluid being essentially heavy hydrocarbon oil, substantially free or free of non-heavy hydrocarbon oil substances, at a temperature of at least 320° C., is passed through the local constriction of the flow-through, hydrodynamic cavitation apparatus to form cavitation bubbles. The cavitation bubbles are collapsed under static pressure to treat the fluid. The treated fluid is extracted from the cavitation apparatus wherein the treated fluid has a viscosity of at least 80 percent less than the viscosity of the fluid prior to passing through the cavitation apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 shows a flow diagram of a process for treating hydrocarbon oil.

[0009] FIG. 2 shows a cross section view of a cavitation apparatus.

[0010] FIG. 3 shows a cross section view of a cavitation apparatus.

[0011] FIG. 4 shows a cross section view of a cavitation apparatus.

DETAILED DESCRIPTION

[0012] Herein, when a range such as 5-25 (or 5 to 25) is given, this means preferably at least 5 and, separately and independently, preferably not more than or less than 25. In an example, such a range defines independently not less than 5, and separately and independently, not less than 25.

[0013] Processes for upgrading hydrocarbon oil are described herein. The processes relate to treating hydrocarbon oil, and preferably heavy hydrocarbon oil, by subjecting the hydrocarbon oil to hydrodynamic cavitation to induce destructing forces that can reduce the viscosity and/or increase the API gravity of the hydrocarbon oil. Treatment of hydrocarbon oil, as used herein, relates to the hydrodynamic cavitation of the hydrocarbon oil such that its viscosity is reduced and/or API gravity is increased. Hydrodynamic cavitation as described below yields high pressure, such as above 600 psi, and high temperature, such as above 380° C., processing conditions that are desirable for effectively treating hydrocarbon oil.

[0014] In general, cavitation can be described as the generation, subsequent growth and collapse of cavitation bubbles. During the collapse of the cavitation bubbles, high-localized pressures and temperatures are achieved, with some estimations of 5000° C. and pressure of approximately 500 kg/cm² (K. S. Suslick, Science, Vol. 247, 23 Mar. 1990, pgs. 1439-1445). High temperatures and pressures can create destructive forces which may not be possible under ordinary conditions, such as standard temperature and pressure, STP. Thus, it is possible to provide physical changes to a substance under the influence of cavitation. Without intending to be bound by any one theory, it is believed that the applying cavitation energy and quickly achieving significant physical characteristic changes, such as within seconds or less, may reduce the cost of treating hydrocarbon oils.

[0015] The cavitation treatment of the hydrocarbon oil can create treated hydrocarbon oil having improved and stable physical characteristics, such as reduced viscosity and increased API gravity. The treated and stable hydrocarbon oil having increased API gravity and/or reduced viscosity pref-

erably retains the upgraded physical properties over time or permanently such that the improved API gravity and/or viscosity parameters do not return to original values as measured in the pre-processed or untreated hydrocarbon oil.

[0016] The hydrocarbon oil can be heavy hydrocarbon oil having high viscosity and/or low API gravity, which can cause the oil to be difficult to pump and process. A heavy hydrocarbon oil includes oil having a high viscosity and/or an API gravity less than about 23 degree, such as that found in oils extracted from oil sands, or materials such as atmospheric tar bottoms products, vacuum tar bottoms products, heavy cycle oils, shale oils, coal-derived liquids, crude oil residue, topped crude oils and the like.

[0017] In one embodiment, provided is a process for treating fluid being hydrocarbon oil, and preferably heavy hydrocarbon oil, by subjecting it to hydrodynamic cavitation to reduce the viscosity and/or increase the API gravity of the hydrocarbon oil. Preferably, the hydrocarbon oil is treated with hydrodynamic cavitation without mixing the hydrocarbon oil with a non-hydrocarbon oil substance such that the hydrocarbon oil is treated in absence of a non-hydrocarbon oil substance or is substantially free of non-hydrocarbon oil substances, for example, less than 1 weight percent, more preferably less than 0.5 weight percent and more preferably less than 0.1 weight percent of a non-hydrocarbon oil substance as measured by weight of the hydrocarbon oil to be treated. For example, non-hydrocarbon oil substances can include, but are not limited to, gases, such as hydrogen gas, catalysts, caustic, organic materials, organic solvents, such as pentane, liquefied petroleum gases, alcohols, such as ethanol and methanol, ethers, water or steam, and mixtures thereof. Although hydrocarbon oil inherently contains a mixture of materials, for purposes herein, hydrocarbon oil is not mixed with non-hydrocarbon oil substances or individual components present in the hydrocarbon oil prior to processing through the cavitation apparatus.

[0018] In another embodiment, the process for treating fluid being hydrocarbon oil, and preferably heavy hydrocarbon oil, by subjecting it to hydrodynamic cavitation to reduce the viscosity and/or increase the API gravity of the hydrocarbon oil is completed in the absence of other cavitation techniques, such as the use of ultrasonic or acoustic energy or sound waves, for example from an ultrasonic horn, to induce cavitation. Thus, the flow-through, hydrodynamic cavitation apparatus can exclude external devices for emitting ultrasonic or acoustic cavitation.

[0019] In another embodiment, the process for treating fluid being hydrocarbon oil, and preferably heavy hydrocarbon oil, by subjecting it to hydrodynamic cavitation to reduce the viscosity and/or increase the API gravity of the hydrocarbon oil is completed in the absence of other cavitation techniques, such as dynamic devices that produce hydrodynamic cavitation. Dynamic devices can include moving or rotating parts that promote or induce cavitation as a function of shearing forces caused by moving mechanical or magnetic parts of such devices. The flow-through, hydrodynamic cavitation apparatus is preferably a static cavitation apparatus containing no moving parts such that cavitation is induced by forcing or actively passing fluid through the static cavitation apparatus to produce a cavitation zone at or near a stationary local constriction in the apparatus, such as an orifice. As discussed in the Examples below, cavitation energy can be created by

passing the fluid through a static cavitation reactor having one or more orifices, either in a single pass or cycle or multiple passes as desired.

[0020] Turning to the figures, FIG. 1 shows a schematic flow diagram of a process for treating hydrocarbon oil. Hydrocarbon oil feedstock is provided in storage vessel 1. The storage vessel 1 can be an atmospheric or pressurized tank, and further include a heating means, such as a heating jacket, for heating the hydrocarbon oil feedstock prior to treatment. Hydrocarbon oil feedstock can be dense (low API gravity, such as in the range of 10 to 23 degree) and have a high viscosity, such as above 200 cSt at a temperature of 50° C., which can make the hydrocarbon oil difficult to pump. Preheating the hydrocarbon oil feedstock can increase flowability and ease pumping for purposes of processing. The hydrocarbon oil feedstock 2 can be drawn from storage vessel 1 to feed pump 3 for transferring the pumped hydrocarbon oil 4 to heat exchanger 10.

[0021] The hydrocarbon oil 4 stream can be heated to a temperature in the range of 300° to 500° C. by any conventional heating method, such as by one or a combination of heating components. As shown, the hydrocarbon oil 4 stream can be heated by passing through heat exchanger 10. The preheated hydrocarbon oil 11 can be further heated in a heat exchanger 12, such as an oven. The heated hydrocarbon oil 13 can be fed to a flow-through cavitation apparatus 14 for inducing cavitation treatment of the hydrocarbon oil 13. The flow-through cavitation apparatus 14 preferably includes at least one local constriction, such as an orifice, one or more baffles, or nozzle, for statically generating a hydrodynamic cavitation zone. The flow-through cavitation apparatus 14 can be as described in U.S. Pat. Nos. 5,810,052; 5,931,771; 5,937,906; 5,971,601; 6,012,492; 6,502,979; 6,802,639 and 6,857,774.

[0022] The flow-through cavitation apparatus 14 can create a hydrodynamic cavitation zone containing cavitation bubbles. The cavitation bubbles are generated by passing the hydrocarbon oil 13 through the local constriction of the cavitation apparatus 14 at an inlet pressure of at least 300, 500, 800, 1000, 1300, 1500, 1800, 2000, 2300, 2600 or 2900 psi. The pressure drop across the local constriction can be at least 300, 500, 800, 1000, 1200, 1500, 1800, 2000, 2200 or 2500 psi. The cavitation bubbles can be maintained in the hydrodynamic cavitation zone for less than 0.1, 0.05, 0.01, 0.005, 0.0025 or 0.001 second. The cavitation bubbles are collapsed under static pressure downstream of the local constriction of the cavitation apparatus 14. The collapsing of the cavitation bubbles induces treatment of the hydrocarbon oil thereby increasing the API gravity of the hydrocarbon oil and/or reducing the viscosity of the hydrocarbon oil, as compared to values measured prior to passing the untreated hydrocarbon oil through the cavitation apparatus. The static pressure for collapsing the cavitation bubbles is at least 150 psi, and preferably in the range of 150-600, 150-400 or 200-400 psi.

[0023] The treated hydrocarbon oil 15 downstream of the flow-through, hydrodynamic cavitation apparatus 14 can have an API gravity increase (i.e. lighter) of greater than 20, 30, 40, 50, 60, 70, 80, 85, 90, 95 or 98 percent. For instance, the API gravity of the treated hydrocarbon oil 15 can be 1, 1.5, 2, 2.5, 3, 4, 5, 6, 7, 8, 9 or 10 degree higher than the untreated hydrocarbon oil 2. The treated hydrocarbon oil 15 can have a viscosity reduction of at least 30, 40, 50, 60, 70, 80, 85, 90, 95 or 99.5 percent. For instance, the viscosity of the treated hydrocarbon oil 15 can be 100, 200, 500, 700, 800, 900, 1,000, 5,000, 10,000, 15,000, 20,000, 25,000 or 30,000 centiStokes (cSt) lower than the untreated hydrocarbon oil 2.

[0024] The treated hydrocarbon oil 15 can be used as a heating medium for pre-heating the pre-processed or untreated hydrocarbon oil stream 9. For example, the treated hydrocarbon oil 15, which can be at a temperature of 300° to 500° C., 320° to 480° C., or 400° to 460° C., can be passed through heat exchanger 10 before being cooled later to result in an upgraded hydrocarbon oil 16 having improved viscosity and/or API gravity characteristics. The heat exchange from the treated hydrocarbon oil 15 to the pre-processed hydrocarbon oil 9 also functions to cool the treated hydrocarbon oil 15.

[0025] FIG. 2 shows a flow-through, hydrodynamic cavitation apparatus 14 having a local constriction 21, such as an orifice 22, for statically treating hydrocarbon oil 13 via hydrodynamic cavitation. The orifice 22 can be any shape, for example, cylindrical, conical, oval, right-angled, square, etc. Depending on the size and shape of the orifice 22, the shape of the cavitation zone flowing at or downstream from the local constriction 21 can be controlled. The orifice 22 can have any diameter, D_2 , for example, the diameter can be greater than 0.1, 0.2, 0.3, 0.4, 0.6, 0.8, 1, 2, 5, 10 or 20 mm. In one example, the orifice 22 diameter can be about 0.3 mm to about 1 mm.

[0026] Alternatively, the local constriction 21 can include baffles, nozzles and the like. Although not shown, the flow-through channel 20, such as a pipe or tube, can have two or more local constrictions in series, such as a first local constriction having one orifice of a desired diameter and a second local constriction having one orifice of a desired diameter. The diameters of the first and second orifices can be the same or may vary.

[0027] As shown, the first chamber 23 has a static pressure P_1 and the second chamber 24 has a static pressure P_2 . Hydrocarbon oil flow 13 into the apparatus 14 can be provided with the aid of fluid pumping devices as known in the art, such as a pump, centrifugal pump, positive-displacement pump or diaphragm pump. An auxiliary pump can provide flow under a static pressure P_1 , or the processing pressure, to the first chamber 23. The processing pressure is preferably at least 200, 500, 700, 1,000, 1,400, 1,800, 2,200, 2,500 or 2,900 psi. The processing pressure is reduced as the hydrocarbon oil 13 passes through the flow-through channel 20 and orifice 22. Maintaining a pressure differential across the orifice 22 allows control of the cavitation intensity in the hydrodynamic cavitation zone in the flow-through channel 20 near or downstream of the local constriction 21. The pressure differential across the orifice 22 is preferably at least 300, 500, 800, 1000, 1200, 1500, 1800, 2000, 2200 or 2500 psi. The velocity of the hydrocarbon oil 13 through the orifice 22 in the apparatus 14 is preferably at least 1, 5, 10, 15, 20, 25, 30, 40, 50, 60 or 70 meters per second (m/s).

[0028] The length (l) of the orifice 22 in the local constriction 21 is selected to adjust the residence time of the cavitation bubbles in the orifice 22 and/or the second chamber 24 housing the cavitation zone to be less than 0.1, 0.05, 0.01, 0.005, 0.0025 or 0.001 second. Downstream 25 of the orifice 22, a valve 26 can be used to adjust the desired static pressure P_2 for collapsing the cavitation bubbles downstream of the local constriction of the cavitation apparatus 14 wherein the valve 26 can provide controlled flow cavitation. The treated hydrocarbon oil 30 exits or is extracted from the valve 26 before being subsequently cooled.

[0029] FIG. 3 illustrates a flow-through cavitation apparatus 14 having a sharp-edged orifice 33 for generating a hydrodynamic cavitation zone for treating hydrocarbon oil 13. The

sharp-edged orifice 33 has a diameter, D_2 , in the range of 0.2 to 100 mm, which faces upstream towards chamber 34. The orifice 33 expands along the length of the local constriction 32 and towards the second chamber 35 at an angle in the range of 10 to 60 degrees. The flow-through channel 36 has an inlet diameter, D_1 , in the range of 0.25 to 80 inches. The local constriction 32 divides the flow-through channel 36 into a first chamber 34 having static pressure P_1 and a second chamber 35 having static pressure P_2 . Preferably, static pressure P_2 induces the collapse of cavitation bubbles and is greater than 150 psi, and more preferably greater than 300 psi. In operation, hydrocarbon oil 13 passes through the flow-through channel 36 and through the local flow constriction 32 to generate cavitation bubbles that are collapsed under static pressure P_2 in the second chamber 35 to produce treated hydrocarbon oil 30 that is extracted from the second chamber 35 before being subsequently cooled.

[0030] Although not shown, the flow-through channel 36 can have additional local constrictions or control measures, such as a valve, downstream of the first local constriction 32 in order to alter the cavitation conditions and static pressure P_2 and provide for a controlled flow. The additional local constriction can be adjustable, for example a valve, or non-adjustable, for example an orifice.

[0031] In another embodiment, FIG. 4 provides a cross section view of a flow-through, hydrodynamic cavitation apparatus 14. A bluff body 43 is positioned in the flow-through channel 40 to create local constrictions, wherein two local constrictions are created in parallel to one another, each local constriction is positioned between the inner wall of the flow-through channel 40 and the top or bottom surface of the bluff body 43, 44. The local constrictions divide the flow-through channel 40 into two chambers, a first chamber 41 having static pressure and a second cavitation chamber 42 having static pressure. The second chamber 42 houses the hydrodynamic cavitation zone as discussed above. In operation, hydrocarbon oil 13 passes through the flow-through channel 40 and around bluff body 43 to generate cavitation bubbles in a cavitation zone downstream of the local constriction that are subsequently collapsed under static pressure in the second cavitation chamber 42.

[0032] Although not shown, the flow-through channel 40 can have two or more bluff bodies or local constrictions, such as an orifice, in series. For example, a first cone-shaped bluff body having a desired diameter and a second cone-shaped bluff body having a desired diameter can be arranged in series. The diameters of the first and second bluff bodies can be the same or may vary.

[0033] In order to promote a further understanding of the invention, the following examples are provided. These examples are shown by way of illustration and not limitation. The hydrocarbon oil treatment process of Examples 1 through 5 was carried out in a flow-through cavitation apparatus substantially similar to the cavitation apparatus 14 as shown in FIG. 2 herein. The cavitation apparatus included a single orifice having a diameter in the range of 0.012 inches (0.3 mm) to 0.014 inches (0.36 mm) and was capable of operating at a pressure of up to 3,000 psi with a nominal flow rate of up to 300 mL/min.

EXAMPLE 1

[0034] A feed stock of Canadian heavy crude oil was used. The Canadian heavy crude oil had an average API gravity of 12.0 degree, and a kinematic viscosity of 999.7 cSt at a temperature of 50° C.

[0035] The Canadian heavy crude oil was passed through a pipe at a processing pressure of 1,950 psi and at a temperature of 460° C. by a high pressure pump. The heated hydrocarbon oil was pumped through a cavitation apparatus having a single orifice of diameter 0.3 mm. The pressure drop across the orifice was sufficient to generate a hydrodynamic cavitation zone containing cavitation bubbles that were collapsed downstream of the orifice under a static pressure of 400 psi. The pressure drop across the orifice was about 1,550 psi. The treated hydrocarbon oil (i.e. downstream of the hydrodynamic cavitation zone) was passed through a heat exchanger and the temperature of the treated hydrocarbon oil was reduced to 40° C.

[0036] The treated hydrocarbon oil had an API gravity of 14.5 degree and a kinematic viscosity of 68.6 cSt at 50° C. The treated hydrocarbon oil had an increase in API gravity of about 21 percent and a reduction in viscosity of about 93 percent. The increased API gravity and reduced viscosity of the treated hydrocarbon oil did not reverse and return to original values.

EXAMPLE 2

[0037] A feed stock of Canadian heavy crude oil was used. The Canadian heavy crude oil had an average API gravity of 10.3 degree, and a kinematic viscosity of 1077.0 cSt at a temperature of 50° C.

[0038] The Canadian heavy crude oil was passed through a pipe at a processing pressure of 1,800 psi and at a temperature of 420° C. by a high pressure pump. The heated hydrocarbon oil was pumped through a cavitation apparatus having a single orifice of diameter 0.3 mm. The pressure drop across the orifice was sufficient to generate a hydrodynamic cavitation zone containing cavitation bubbles that were collapsed downstream of the orifice under a static pressure of 360 psi. The pressure drop across the orifice was about 1,440 psi. The treated hydrocarbon oil (i.e. downstream of the hydrodynamic cavitation zone) was passed through a heat exchanger and the temperature of the treated hydrocarbon oil was reduced to 40° C.

[0039] The treated hydrocarbon oil had an API gravity of 15.3 degree and a kinematic viscosity of 130.5 cSt at 50° C. The treated hydrocarbon oil had an increase in API gravity of about 49 percent and a reduction in viscosity of about 88 percent. The increased API gravity and reduced viscosity of the treated hydrocarbon oil did not reverse and return to original values.

EXAMPLE 3

[0040] A feed stock of Canadian heavy crude oil was used. The Canadian heavy crude oil had an average API gravity of 10.7 degree, and a kinematic viscosity of 1031.0 cSt at a temperature of 50° C.

[0041] The Canadian heavy crude oil was passed through a pipe at a processing pressure of 2,839 psi and at a temperature of 328° C. by a high pressure pump. The heated hydrocarbon oil was pumped through a cavitation apparatus having a single orifice of diameter 0.36 mm. The pressure drop across the orifice was sufficient to generate a hydrodynamic cavitation zone containing cavitation bubbles that were collapsed downstream of the orifice under a static pressure of 308 psi. The pressure drop across the orifice was about 2,531 psi. The treated hydrocarbon oil (i.e. downstream of the hydrodynamic

cavitation zone) was passed through a heat exchanger and the temperature of the treated hydrocarbon oil was reduced to 40° C.

[0042] The treated hydrocarbon oil had an API gravity of 18.1 degree and a kinematic viscosity of 49.3 cSt at 50° C. The treated hydrocarbon oil had an increase in API gravity of about 69 percent and a reduction in viscosity of about 95 percent. The increased API gravity and reduced viscosity of the treated hydrocarbon oil did not reverse and return to original values.

EXAMPLE 4

[0043] A feed stock of United States heavy crude oil was used. The United States heavy crude oil had an average API gravity of 14.8 degree, and a kinematic viscosity of 262.4 cSt at a temperature of 50° C.

[0044] The United States heavy crude oil was passed through a pipe at a processing pressure of 2,450 psi and at a temperature of 400° C. by a high pressure pump. The heated hydrocarbon oil was pumped through a cavitation apparatus having a single orifice of diameter 0.3 mm. The pressure drop across the orifice was sufficient to generate a hydrodynamic cavitation zone containing cavitation bubbles that were collapsed downstream of the orifice under a static pressure of 300 psi. The pressure drop across the orifice was about 2,150 psi. The treated hydrocarbon oil (i.e. downstream of the hydrodynamic cavitation zone) was passed through a heat exchanger and the temperature of the treated hydrocarbon oil was reduced to 40° C.

[0045] The treated hydrocarbon oil had an API gravity of 20.9 degree and a kinematic viscosity of 8.4 cSt at 50° C. The treated hydrocarbon oil had an increase in API gravity of about 41 percent and a reduction in viscosity of about 97 percent. The increased API gravity and reduced viscosity of the treated hydrocarbon oil did not reverse and return to original values.

EXAMPLE 5

[0046] A feed stock of Newalta heavy crude oil was used. The Newalta heavy crude oil had an average API gravity of 12.4 degree, and a kinematic viscosity of 714.1 cSt at a temperature of 50° C.

[0047] The Newalta heavy crude oil was passed through a pipe at a processing pressure of 1,928 psi and at a temperature of 482° C. by a high pressure pump. The heated hydrocarbon oil was pumped through a cavitation apparatus having a single orifice of diameter 0.36 mm. The pressure drop across the orifice was sufficient to generate a hydrodynamic cavitation zone containing cavitation bubbles that were collapsed downstream of the orifice under a static pressure of 178 psi. The pressure drop across the orifice was about 1,750 psi. The treated hydrocarbon oil (i.e. downstream of the hydrodynamic cavitation zone) was passed through a heat exchanger and the temperature of the treated hydrocarbon oil was reduced to 40° C.

[0048] The treated hydrocarbon oil had an API gravity of 20.7 degree and a kinematic viscosity of 4.4 cSt at 50° C. The treated hydrocarbon oil had an increase in API gravity of about 67 percent and a reduction in viscosity of about 99 percent. The increased API gravity and reduced viscosity of the treated hydrocarbon oil did not reverse and return to original values.

[0049] As can be seen from the Examples, a single pass or cycle through the flow-through, hydrodynamic cavitation apparatus having a single local constriction, such as an orifice, can increase the API gravity of the treated hydrocarbon oil as compared to the pre-processed or untreated hydrocarbon oil prior to being passed through the cavitation apparatus by 2.5 to 8.3 degree, or 21 to 69 percent. Thus, as shown, a pressure drop of at least 1,400 psi can result in an increase of API gravity of at least 2.5 degree. Operating temperatures of at least 300° C., and more preferably over 400° C., were utilized to achieve the reported API gravity increases.

[0050] The Examples further show that the treated hydrocarbon oil, as compared to the pre-processed hydrocarbon oil prior to being passed through the cavitation apparatus, can have a reduced viscosity in the range of 254 to 982 cSt at a temperature of 50° C., or 88 to 99 percent. The increase in API gravity and reduction in viscosity occurred over a pressure drop range of 1,440 to 2,531 psi. Pressure drops of at least 1,500 psi over the local constriction resulted in viscosity reduction of at least 93% and a pressure drop of at least 1,750 psi resulted in viscosity reduction of at least 95%. Operating temperatures of at least 300° C., and more preferably over 400° C., were utilized to achieve the reported viscosity reductions.

[0051] It will be understood that this invention is not limited to the above-described embodiments. Those skilled in the art having the benefit of the teachings of the present invention as hereinabove set forth, can effect numerous modifications thereto. These modifications are to be construed as being encompassed with the scope of the present invention as set forth in the appended claims.

What is claimed is:

1. A process for treating a hydrocarbon oil comprising:
 - a) providing a flow-through, hydrodynamic cavitation apparatus having a local constriction;
 - b) passing a hydrocarbon oil through the local constriction of the flow-through, hydrodynamic cavitation apparatus such that cavitation bubbles are formed, wherein a substance that is not a hydrocarbon oil is not passed through the local constriction of the flow-through, hydrodynamic cavitation apparatus;
 - c) collapsing the cavitation bubbles under static pressure to treat the hydrocarbon oil;
 - d) extracting the treated hydrocarbon oil from the flow-through, hydrodynamic cavitation apparatus, wherein the treated hydrocarbon oil has increased API gravity as compared to the hydrocarbon oil prior to passing through the flow-through, hydrodynamic cavitation apparatus.
2. The process of claim 1, the substance that is not a hydrocarbon oil being hydrogen gas.
3. The process of claim 1, the substance that is not a hydrocarbon oil being an organic material.
4. The process of claim 1, the API gravity of the hydrocarbon oil being increased by more than 2 units, the API gravity remaining increased by more than 2 degree for at least 2 weeks.
5. The process of claim 1, the treated hydrocarbon oil having a reduction in viscosity of at least 80 percent.
6. The process of claim 1, passing the hydrocarbon oil through the local constriction of the flow-through, hydrodynamic cavitation apparatus at a pre-determined pressure to achieve a pressure drop across the local constriction of at least 1000 psi.
7. The process of claim 1, the hydrocarbon oil being treated in the absence of ultrasonic cavitation.

8. The process of claim 1, the flow-through, hydrodynamic cavitation apparatus being a static cavitation apparatus.

9. A process for treating a hydrocarbon oil comprising:

- a) providing a flow-through, hydrodynamic cavitation apparatus having a local constriction;
- b) passing a hydrocarbon oil through the local constriction of the flow-through, hydrodynamic cavitation apparatus such that cavitation bubbles are formed, wherein a substance that is not a hydrocarbon oil is not passed through the local constriction of the flow-through, hydrodynamic cavitation apparatus;
- c) collapsing the cavitation bubbles under static pressure to treat the hydrocarbon oil;
- d) extracting the treated hydrocarbon oil from the flow-through, hydrodynamic cavitation apparatus, wherein the treated hydrocarbon oil has reduced viscosity as compared to the hydrocarbon oil prior to passing through the flow-through, hydrodynamic cavitation apparatus.

10. The process of claim 9, the substance that is not a hydrocarbon oil being hydrogen gas.

11. The process of claim 9, the substance that is not a hydrocarbon oil being an organic material.

12. The process of claim 11, the organic material being an organic solvent or water.

13. The process of claim 9, the viscosity of the hydrocarbon oil being reduced by at least 80 percent, the viscosity remaining reduced by at least 80 percent for at least 2 weeks.

14. The process of claim 9, the treated hydrocarbon oil having an increase in API gravity of at least 2 degree.

15. The process of claim 9, passing the hydrocarbon oil through the local constriction of the flow-through, hydrodynamic cavitation apparatus at a pre-determined pressure to achieve a pressure drop across the local constriction of at least 1000 psi.

16. The process of claim 9, the hydrocarbon oil being treated in the absence of ultrasonic cavitation.

17. The process of claim 9, the hydrocarbon oil being passed through the local constriction of the flow-through, hydrodynamic cavitation apparatus not more than one cycle.

18. The process of claim 9, the hydrocarbon oil being heated to at least 320° C. prior to passing through the local constriction of the flow-through, hydrodynamic cavitation apparatus.

19. The process of claim 9, the static pressure being at least 150 psi.

20. A process for reducing the viscosity of a heavy hydrocarbon oil comprising the steps of:

- a) providing a flow-through, hydrodynamic cavitation apparatus having a local constriction;
- b) passing a preheated fluid consisting of a heavy hydrocarbon oil at a temperature of at least 320° C. through the local constriction of the flow-through, hydrodynamic cavitation apparatus to form cavitation bubbles;
- c) collapsing the cavitation bubbles under static pressure to treat the fluid;
- d) extracting the treated fluid from the flow-through, hydrodynamic cavitation apparatus, wherein the treated fluid has viscosity at least 80 percent less than the viscosity of the fluid prior to passing through the flow-through, hydrodynamic cavitation apparatus.