Innovation, Sciences et Développement économique Canada
Office de la Propriété Intellectuelle du Canada

Innovation, Science and Economic Development Canada
Canadian Intellectual Property Office

CA 3105221 A1 2022/07/08

(21) **3 105 221**

(12) **DEMANDE DE BREVET CANADIEN**
CANADIAN PATENT APPLICATION

(13) **A1**

(22) Date de dépôt/Filing Date: 2021/01/08

(41) Mise à la disp. pub./Open to Public Insp.: 2022/07/08

(51) Cl.Int./Int.Cl. *C10C 3/08* (2006.01)

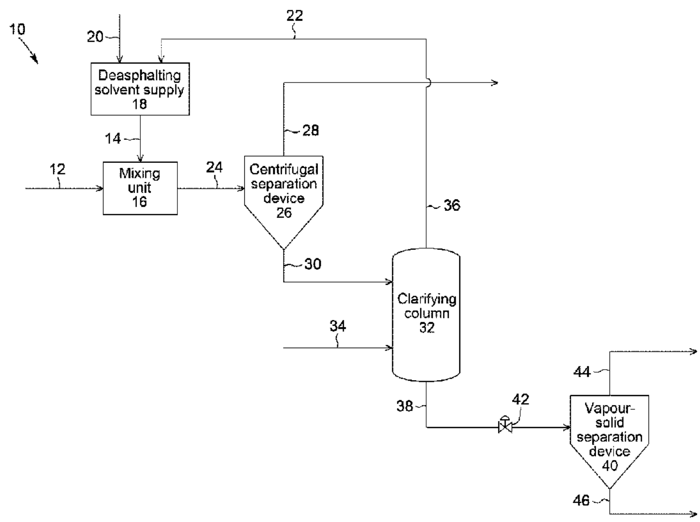
(71) Demandeur/Applicant:
SUNCOR ENERGY INC., CA

(72) Inventeurs/Inventors:
REMESAT, DARIUS, CA;
SUN, ANNIE, CA

(74) Agent: ROBIC

(54) Titre : DESASPHALTAGE PAR SOLVANT DE FLUX D'HYDROCARBURES LOURDS AU MOYEN D'HYDROCYCLONES

(54) Title: SOLVENT DEASPHALTING OF HEAVY HYDROCARBON STREAMS USING HYDROCYCLONES



(57) Abrégé/Abstract:
A process and system for solvent deasphalting a bitumen-containing feedstock are described. The process can include solvent deasphalting the bitumen-containing feedstock, which can include contacting the bitumen-containing feedstock with a deasphalting solvent to induce precipitation of asphaltenes and produce a diluted bitumen stream comprising deasphalted oil and asphaltene precipitates, and subjecting the diluted bitumen stream to centrifugal separation to recover an overflow stream comprising diluted deasphalted oil and an underflow stream comprising the asphaltene precipitates and residual deasphalting solvent. The process can also include subjecting the underflow stream to separation in a clarifying column to produce a solvent fraction enriched in solvent and depleted in asphaltene precipitates, and an asphaltenes fraction enriched in asphaltene precipitates. Also described is a process for producing a diluent-derived deasphalting solvent from deasphalted oil, and a mixing device for contacting a bitumen-containing feedstock stream with a deasphalting solvent stream to produce a diluted bitumen stream.

ABSTRACT

A process and system for solvent deasphalting a bitumen-containing feedstock are described. The process can include solvent deasphalting the bitumen-containing feedstock, which can include contacting the bitumen-containing feedstock with a deasphalting solvent to induce precipitation of asphaltenes and produce a diluted bitumen stream comprising deasphalted oil and asphaltene precipitates, and subjecting the diluted bitumen stream to centrifugal separation to recover an overflow stream comprising diluted deasphalted oil and an underflow stream comprising the asphaltene precipitates and residual deasphalting solvent. The process can also include subjecting the underflow stream to separation in a clarifying column to produce a solvent fraction enriched in solvent and depleted in asphaltene precipitates, and an asphaltenes fraction enriched in asphaltene precipitates. Also described is a process for producing a diluent-derived deasphalting solvent from deasphalted oil, and a mixing device for contacting a bitumen-containing feedstock stream with a deasphalting solvent stream to produce a diluted bitumen stream.

015364-0440

Date Reçue/Date Received 2021-01-08

SOLVENT DEASPHALTING OF HEAVY HYDROCARBON STREAMS USING HYDROCYCLONES

TECHNICAL FIELD

[001] The technical field generally relates to the treatment of bitumen-containing streams, and more particularly to solvent deasphalting of bitumen-containing streams using hydrocyclones.

BACKGROUND

[002] Bitumen generally has a high viscosity, irrespective of whether it has been recovered by mining operations or by *in situ* recovery processes. This high viscosity can make the pipeline transportation of bitumen difficult. Various methods exist to upgrade bitumen to decrease its viscosity and increase suitability for pipeline transportation, although such methods have various drawbacks.

[003] Asphaltenes are a component of bitumen that contribute significantly to its high viscosity. Asphaltenes present in bitumen can also precipitate at undesired locations within pieces of process equipment and pipelines, and can cause problems such as fouling and plugging.

[004] Solvent deasphalting is a technique that can be used to separate asphaltenes from bitumen. Solvent deasphalting generally involves contacting bitumen with a deasphalting solvent, such as a paraffinic solvent (*e.g.*, propane or butane). The deasphalting solvent is used to destabilize asphaltenes by breaking “physical” bonds between asphaltenes groups and resin molecules. Depending on the characteristics of the deasphalting solvent and the amount added relative to the bitumen, mixing of the deasphalting solvent with the bitumen can result in the formation of an asphaltene-enriched phase, or residue, and a deasphalted oil phase, which can be separated from one another. Asphaltenes can also precipitate and be selectively separated from the bitumen. Solvent deasphalting can thus produce a stream of deasphalted oil having a reduced asphaltenes content and a reduced viscosity, thus providing suitable properties to be pipelinable.

Date Reçue/Date Received 2021-01-08

[005] Different techniques can be used to separate the asphaltene-enriched phase from the rest of the bitumen that has been subjected to solvent deasphalting, and those techniques can depend on the conditions at which the solvent deasphalting is operated. For instance, solvent deasphalting can be performed at temperatures above the softening point of the asphaltenes, such that the production of asphaltene precipitates does not occur too early in the process and lead to plugging of process equipment. As mentioned above, the choice of deasphalting solvent can also influence the characteristics of the asphaltene precipitates, with regard for instance to their softening point. For example, a higher molecular weight paraffinic solvent, such as pentane or hexane, can produce asphaltene precipitates having a low content of deasphalted oil and a high softening point, which in turn can lead to plugging of process equipment. On the other hand, deasphalted oil lost to asphaltene precipitates can be economically undesirable. Depending on the technique that is used, large solvent inventory can be necessary to achieve efficient separation of the asphaltenes and to compensate for solvent lost to the asphaltene precipitates, which also has economic drawbacks.

[006] Various challenges exist in terms of technologies for treating and upgrading bitumen via solvent deasphalting.

SUMMARY

[007] In accordance with an aspect, there is provided a process for treating a bitumen-containing feedstock, comprising:

solvent deasphalting the bitumen-containing feedstock, comprising:

contacting the bitumen-containing feedstock with a deasphalting solvent to induce precipitation of asphaltenes contained in the bitumen-containing feedstock and produce a diluted bitumen stream comprising deasphalted oil and asphaltene precipitates; and

subjecting the diluted bitumen stream to centrifugal separation in a centrifugal separation device to recover an overflow stream comprising diluted deasphalted oil and an underflow stream comprising the asphaltene precipitates and residual deasphalting solvent; and

Date Reçue/Date Received 2021-01-08

subjecting the underflow stream from the centrifugal separation device to separation in a clarifying column to produce a solvent fraction enriched in solvent and depleted in asphaltene precipitates, and an asphaltenes fraction enriched in asphaltene precipitates.

[008] In some implementations, the centrifugal separation device comprises one or more hydrocyclones.

[009] In some implementations, the centrifugal separation device is operated at a temperature ranging from about 50°C to about 10°C below a critical point of the deasphalting solvent.

[0010] In some implementations, the centrifugal separation device is operated at a temperature ranging from about 40°C to about 20°C below a critical point of the deasphalting solvent.

[0011] In some implementations, the centrifugal separation device is operated at a temperature ranging from about 100°C to about 250°C.

[0012] In some implementations, the centrifugal separation device is operated at a temperature ranging from about 120°C to about 220°C.

[0013] In some implementations, the centrifugal separation device is operated at a pressure ranging from about 1200 kPa to about 3000 kPa.

[0014] In some implementations, the asphaltenes precipitates have a softening point above pyrolysis temperature at operating conditions of the centrifugal separation device.

[0015] In some implementations, the contacting of the bitumen-containing feedstock with the deasphalting solvent is performed using a mixing device.

[0016] In some implementations, the mixing device comprises at least one of a static mixer, a shear mixer, and a mixing tee.

[0017] In some implementations, the mixing device comprises a mixing tee.

Date Reçue/Date Received 2021-01-08

[0018] In some implementations, the mixing tee comprises a feedstock section within which flows the bitumen-containing feedstock and a solvent section within which flows the deasphalting solvent, the solvent section being in fluid communication with the feedstock section.

[0019] In some implementations, the feedstock section and the solvent section are provided at an angle ranging from about 170° to about 190° relative to each other.

[0020] In some implementations, contacting the bitumen-containing feedstock with the deasphalting solvent comprises:

flowing the bitumen-containing feedstock in a first direction within the feedstock section; and

flowing the deasphalting solvent in a second direction within the solvent section, the second direction comprising at least one directional component opposite to the first direction, such that the bitumen-containing feedstock and the deasphalting solvent collide in a mixing zone to form the diluted bitumen stream and initiate formation of the asphaltene precipitates.

[0021] In some implementations, the mixing tee further comprises an output section within which flows the diluted bitumen stream.

[0022] In some implementations, the solvent section comprises a valve operable to increase a velocity at which the deasphalting solvent collides into the bitumen-containing feedstock in the mixing zone.

[0023] In some implementations, the bitumen-containing feedstock is flowed in the first direction within the feedstock section at a Reynolds number above about 200.

[0024] In some implementations, the bitumen-containing feedstock is flowed in the first direction within the feedstock section at a Reynolds number ranging from about 2000 to about 5000.

[0025] In some implementations, the deasphalting solvent is flowed in the second direction within the solvent section at a Reynolds number above about 4000.

Date Reçue/Date Received 2021-01-08

[0026] In some implementations, the deasphalting solvent is flowed in the second direction within the solvent section at a Reynolds number ranging from about 30 000 to about 35 000.

[0027] In some implementations, the asphaltene precipitates of the underflow stream from the centrifugal separation device comprise less than about 40 wt% of residual deasphalted oil.

[0028] In some implementations, the asphaltene precipitates of the underflow stream from the centrifugal separation device comprise between about 20 wt% and 35 wt% of residual deasphalted oil.

[0029] In some implementations, the asphaltene precipitates of the underflow stream from the centrifugal separation device comprise between about 25 wt% and 30 wt% of residual deasphalted oil.

[0030] In some implementations, the deasphalting solvent comprises an alkane-based solvent.

[0031] In some implementations, the alkane-based solvent comprises at least one of propane, butane, pentane, hexane heptane, and octane, or a combination thereof.

[0032] In some implementations, the deasphalting solvent comprises branched hydrocarbons.

[0033] In some implementations, the branched hydrocarbons comprises isopentane.

[0034] In some implementations, the deasphalting solvent comprises hydrocarbons having cyclic structures.

[0035] In some implementations, the hydrocarbons having cyclic structures comprises as least one of cyclopentane and cyclohexane.

[0036] In some implementations, the process further comprises subjecting the overflow stream from the centrifugal separation device to separation in a deasphalted oil/solvent separator.

Date Reçue/Date Received 2021-01-08

[0037] In some implementations, the deasphalted oil/solvent separator is a stripping unit.

[0038] In some implementations, subjecting the overflow stream from the centrifugal separation device to separation in the deasphalted oil/solvent separator comprises introducing a stripping fluid into the deasphalted oil/solvent separator.

[0039] In some implementations, the stripping fluid comprises at least one of natural gas and steam.

[0040] In some implementations, subjecting the overflow stream from the centrifugal separation device to separation in the deasphalted oil/solvent separator comprises adding a solvent to the deasphalted oil/solvent separator.

[0041] In some implementations, subjecting the overflow stream from the centrifugal separation device to separation in the deasphalted oil/solvent separator comprises adding a diluent to the deasphalted oil/solvent separator.

[0042] In some implementations, the diluent comprises at least one of naphtha or condensate.

[0043] In some implementations, subjecting the overflow stream from the centrifugal separation device to separation in the deasphalted oil/solvent separator comprises flashing a light fraction comprising C_1 to C_8 hydrocarbons.

[0044] In some implementations, subjecting the overflow stream from the centrifugal separation device to separation in the deasphalted oil/solvent separator comprises producing a bottom fraction comprising deasphalted oil.

[0045] In some implementations, the process further comprises separating the light fraction from the deasphalted oil/solvent separator to produce a lighter fraction comprising C_1 to C_4 hydrocarbons and a middle fraction comprising C_5 to C_8 hydrocarbons.

[0046] In some implementations, separating the light fraction from the deasphalted oil/solvent separator comprises condensing the middle fraction.

Date Reçue/Date Received 2021-01-08

[0047] In some implementations, the middle fraction is recyclable as the deasphalting solvent for performing the solvent deasphalting.

[0048] In some implementations, the process further comprises supplying the solvent fraction from the clarifying column to the deasphalted oil/solvent separator.

[0049] In some implementations, the asphaltene precipitates from the asphaltenes fraction comprise between about 15 wt% and 20 wt% of residual deasphalted oil.

[0050] In some implementations, the asphaltene precipitates from the asphaltenes fraction comprise less than 20 wt% of residual deasphalted oil.

[0051] In some implementations, the process further comprises subjecting the asphaltenes fraction to centrifugal separation in an additional centrifugal separation device to further separate solvent therefrom and produce a recovered vaporized solvent stream and dry asphaltene precipitates.

[0052] In some implementations, the additional centrifugal separation device comprises one or more vapour-solid cyclone.

[0053] In some implementations, the dry asphaltene precipitates comprise less than about 10 wt% of residual deasphalted oil.

[0054] In some implementations, the dry asphaltene precipitates comprise between about 5 wt% and 10 wt% of residual deasphalted oil.

[0055] In some implementations, the dry asphaltene precipitates comprise between about 3 wt% and 4 wt% of residual deasphalted oil.

[0056] In some implementations, the dry asphaltene precipitates comprise less than about 7 wt% of residual deasphalted oil.

[0057] In some implementations, the process further comprises condensing the recovered vaporized solvent stream to produce a condensed recovered solvent steam.

[0058] In some implementations, the process further comprises recycling the condensed recovered solvent steam to the clarifying column as a clarifying solvent.

Date Reçue/Date Received 2021-01-08

[0059] In some implementations, the process further comprises recycling the condensed recovered solvent steam for use as the deasphalting solvent.

[0060] In some implementations, the solvent fraction from the clarifying column is recyclable as the deasphalting solvent.

[0061] In some implementations, the process further comprises preventing vapor generation within the centrifugal separation device by providing a backpressure valve downstream of the centrifugal separation device and upstream of the deasphalted oil/solvent separator.

[0062] In some implementations, the process further comprises vaporizing solvent present in the asphaltenes fraction from the clarifying column during pipelining from the clarifying column to the additional centrifugal separation device.

[0063] In some implementations, vaporizing solvent present in the asphaltenes fraction from the clarifying column during pipelining from the clarifying column to the additional centrifugal separation device comprising operating a valve provided on a pipeline carrying the asphaltenes fraction to flash the solvent therefrom.

[0064] In some implementations, the bitumen-containing feedstock comprises bitumen froth obtained from a bitumen froth treatment operation.

[0065] In some implementations, the bitumen-containing feedstock comprises bitumen obtained from an *in situ* recovery operation.

[0066] In some implementations, the bitumen-containing feedstock comprises bitumen obtained from an oil sands mining and extraction operation.

[0067] In some implementations, the bitumen-containing feedstock comprises a heavy bitumen fraction recovered from a distillation column or fractionation column.

[0068] In some implementations, the bitumen-containing feedstock comprises a thermally-affected heavy fraction produced by a thermal treatment.

Date Reçue/Date Received 2021-01-08

[0069] In some implementations, the bitumen-containing feedstock comprises a thermally-affected asphaltene-rich stream produced by a thermal treatment.

[0070] In accordance with another aspect, there is provided a process for producing a diluent-derived deasphalting solvent, comprising:

supplying a feedstock mixture comprising deasphalted oil and deasphalting solvent to a deasphalted oil/solvent separator;

combining the feedstock mixture with a diluent;

operating the deasphalted oil/solvent separator to produce an overhead stream comprising C_1 to C_8 hydrocarbons, and a bottom stream comprising the deasphalted oil; and

separating the overhead stream to produce a vaporized light fraction comprising C_1 to C_4 hydrocarbons and a condensed middle fraction comprising C_5 to C_8 hydrocarbons, the condensed middle fraction for use as the diluent-derived deasphalting solvent.

[0071] In some implementations, the deasphalted oil/solvent separator is a stripping unit.

[0072] In some implementations, operating the deasphalted oil/solvent separator comprises injecting a stripping fluid into the deasphalted oil/solvent separator.

[0073] In some implementations, the stripping fluid comprises at least one of natural gas and steam.

[0074] In some implementations, the diluent comprises at least one of naphtha or condensate.

[0075] In some implementations, combining the feedstock mixture with the diluent comprises introducing the diluent into the deasphalted oil/solvent separator.

[0076] In some implementations, combining the feedstock mixture with the diluent comprises mixing the diluent with the feedstock mixture prior to introduction into the deasphalted oil/solvent separator.

Date Reçue/Date Received 2021-01-08

[0077] In some implementations, the process further comprises combining the diluent-derived deasphalting solvent with a bitumen-containing feedstock to produce a diluted bitumen stream that includes asphaltene precipitates in suspension in deasphalted oil.

[0078] In some implementations, the process further comprises subjecting the diluted bitumen stream to centrifugal separation to produce the mixture comprising the deasphalted oil and the deasphalting solvent.

[0079] In some implementations, the diluent-derived deasphalting solvent is provided in a proportion of about 1.5 to 6 on a mass basis relative to a bitumen content of the bitumen-containing feedstock.

[0080] In some implementations, the diluent-derived deasphalting solvent is provided in a proportion ranging from about 2 to 5 on a mass basis relative to a bitumen content of the bitumen-containing feedstock.

[0081] In some implementations, the diluent-derived deasphalting solvent is provided in a proportion ranging from about 2.5 to 4 on a mass basis relative to a bitumen content of the bitumen-containing feedstock.

[0082] In accordance with another aspect, there is provided a mixing device for contacting a bitumen-containing feedstock stream with a deasphalting solvent stream to produce a diluted bitumen stream, the device comprising:

a pipeline section comprising:

a feedstock section for flowing the bitumen-containing feedstock stream in a first direction;

a solvent section in fluid communication with the feedstock section for flowing the deasphalting solvent stream in a second direction that is opposite the first direction; and

a mixing zone located at a junction of the feedstock section and the solvent section;

Date Reçue/Date Received 2021-01-08

a diluted bitumen section extending from the junction of the feedstock section and the solvent section and being in fluid communication therewith for receiving a diluted bitumen mixture comprising deasphalted oil and asphaltene precipitates; and

a valve provided on the solvent section for increasing a velocity at which the deasphalting solvent contacts the bitumen-containing feedstock in the mixing zone.

[0083] In some implementations, the feedstock section and the solvent section are provided at an angle of 180° relative to each other.

[0084] In some implementations, the feedstock section and the solvent section are provided at an angle of less than 180° relative to each other.

[0085] In some implementations, the feedstock section and the solvent section are provided at an angle of more than 180° relative to each other.

[0086] In some implementations, the diluted bitumen section extends from the pipeline section substantially perpendicularly.

[0087] In some implementations, the diluted bitumen section extends from the pipeline section at an angle ranging from 90° to 45°.

[0088] In some implementations, the feedstock section has a feedstock section diameter and the solvent section has a solvent section diameter, and the feedstock section diameter is larger than the solvent section diameter.

[0089] In some implementations, a ratio of the solvent section diameter relative to the feedstock section diameter ranges from between 0.3 and 0.7.

[0090] In some implementations, the feedstock section is configured to flow the bitumen-containing feedstock at a Reynolds number above about 200.

[0091] In some implementations, the feedstock section is configured to flow the bitumen-containing feedstock at a Reynolds number ranging from about 2000 and about 5000.

[0092] In some implementations, the solvent section is configured to flow the deasphalting solvent at a Reynolds number above about 4000.

Date Reçue/Date Received 2021-01-08

[0093] In some implementations, the solvent section is configured to flow the deasphalting solvent at a Reynolds number ranging from about 30 000 to about 35 000.

[0094] In accordance with another aspect, there is provided a process for contacting a bitumen-containing feedstock stream and a deasphalting solvent stream to produce a diluted bitumen stream, the process comprising:

flowing the bitumen-containing feedstock stream in a first direction within a feedstock section;

flowing the deasphalting solvent stream in a second direction within a solvent section in fluid communication with the feedstock section, the second direction comprising at least one directional component opposite to the first direction;

increasing a velocity of the deasphalting solvent stream received in the solvent section;

contacting the bitumen-containing feedstock stream and the deasphalting solvent stream in a mixing zone located at a junction of the feedstock section and the solvent section to produce diluted deasphalted oil comprising asphaltene precipitates; and

flowing the diluted deasphalted oil in a diluted bitumen section extending from the junction of the feedstock section and the solvent section and being in fluid communication therewith.

[0095] In some implementations, the bitumen-containing feedstock stream is flowed within the feedstock section at a velocity ranging from between about 1 cm/s and about 5 cm/s.

[0096] In some implementations, the deasphalting solvent stream is flowed within the solvent section at a velocity ranging from between about 90 cm/s and about 150 cm/s.

[0097] In some implementations, the velocity of the deasphalting solvent stream received in the solvent section is increased by operating a valve provided on the solvent section.

Date Reçue/Date Received 2021-01-08

[0098] In some implementations, the valve is configured to provide a pressure drop ranging from about 20 psi to about 40 psi.

[0099] In some implementations, the bitumen-containing feedstock stream is flowed in the first direction within the feedstock section at a Reynolds number above about 200.

[00100] In some implementations, the bitumen-containing feedstock stream is flowed in the first direction within the feedstock section at a Reynolds number ranging from about 2000 to about 5000.

[00101] In some implementations, the deasphalting solvent stream is flowed in the second direction within the solvent section at a Reynolds number above about 4000.

[00102] In some implementations, the deasphalting solvent is flowed in the second direction within the solvent section at a Reynolds number ranging from about 30 000 to about 35 000.

[00103] In some implementations, the process further comprises heating the bitumen-containing feedstock stream.

[00104] In some implementations, the bitumen-containing feedstock stream is heated until the viscosity of the bitumen-containing feedstock stream is reduced below about 1000 cSt.

[00105] In some implementations, the bitumen-containing feedstock stream is heated until the viscosity of the bitumen-containing feedstock stream is reduced below about 200 cSt.

BRIEF DESCRIPTION OF THE DRAWINGS

[00106] Figure 1 is a process flow diagram illustrating an example of a solvent deasphalting process.

[00107] Figure 2 is a schematic representation of a mixing tee for contacting a bitumen-containing feedstock and a deasphalting solvent.

[00108] Figure 3 is a process flow diagram illustrating another example of a solvent deasphalting process.

Date Reçue/Date Received 2021-01-08

DETAILED DESCRIPTION

[00109] Techniques described herein relate to a process for treating a bitumen-containing feedstock that comprises asphaltenes, and more particularly to solvent deasphalting to form and separate precipitated asphaltenes from a bitumen-containing feedstock. For example, the process can include solvent deasphalting of the bitumen-containing feedstock, which can include contacting the bitumen-containing feedstock with a deasphalting solvent to induce precipitation of asphaltenes and produce a diluted bitumen stream comprising deasphalted oil and asphaltene precipitates, and then subjecting the diluted bitumen stream to centrifugal separation in a centrifugal separation device to perform a liquid-solid separation and recover an overflow stream comprising diluted deasphalted oil and an underflow stream comprising the asphaltene precipitates and residual deasphalting solvent. The centrifugal separation device can be, for instance, a hydrocyclone.

[00110] In some implementations, the contacting of the bitumen-containing feedstock with the deasphalting solvent can be performed using a mixing tee configuration that includes features facilitating formation of the asphaltene precipitates. For instance, the mixing tee can be configured such that the bitumen-containing feedstock flowing in one direction collides with a flow of deasphalting solvent flowing in an opposite direction with sufficient momentum to promote formation of asphaltene precipitates upon penetration of the deasphalting solvent into the bitumen-containing feedstock. The combined diluted bitumen stream flows away in a third direction, which may be perpendicular with respect to the flow directions of the two incoming streams.

[00111] The underflow stream from the centrifugal separation device can subsequently be transported to a clarifying column to be subjected to solvent separation and produce a solvent fraction enriched in solvent and depleted in asphaltene precipitates, and an asphaltenes fraction enriched in asphaltene precipitates. The clarifying column can be operated in a counter-current fashion where deasphalting solvent is introduced at the bottom or a lower portion of the clarifying column while the underflow stream is introduced as a feed stream at the top or an upper portion of the clarifying column so as to clean the

Date Reçue/Date Received 2021-01-08

asphaltene precipitates to further remove resins therefrom and to recover residual deasphalted oil.

[00112] The combination of a centrifugal separation device, such as a hydrocyclone, and a clarifying column can facilitate the efficient separation of asphaltene precipitates from deasphalted oil and contribute to improve deasphalted oil recovery. In addition, the improved deasphalted oil recovery facilitated by the centrifugal separation device and the clarifying column can contribute to lowering the amount of residual deasphalted oil present in the asphaltene precipitates to less than about 15 wt%, while using less solvent inventory than other techniques aimed at producing asphaltene precipitates with such low contents of residual deasphalted oil.

[00113] Additional separation steps can be implemented to further separate solvent from the asphaltene precipitates. For instance, a vapour-solid cyclone can be used to receive the bottoms of the clarifying column and produce a recovered solvent stream and dry asphaltene precipitates. When a vapour-solid cyclone is used to recover solvent from the asphaltenes fraction, the recovered solvent can be recycled for use in other parts of the solvent deasphalting process.

[00114] Additional separation steps can also be implemented to separate the overflow stream produced by the centrifugal separation device to obtain various hydrocarbon fractions. Such separation steps can be performed in a deasphalted oil/solvent separator, such as a stripping column. For example, the deasphalted oil/solvent separator can be operated to produce a deasphalted oil product, and a light fraction comprising C_1 to C_8 hydrocarbons as an overhead. In some implementations, a make-up diluent, such as naphtha, or a make-up solvent, can be added to the deasphalted oil/solvent separator. The light fraction can subsequently be separated to produce a vaporized lighter fraction comprising C_1 to C_4 hydrocarbons and a middle fraction comprising C_5 to C_8 hydrocarbons. Introduction of diluent, which includes multiple hydrocarbon fractions, as make-up solvent to the deasphalted oil/solvent separator can facilitate the production of the middle fraction comprising C_5 to C_8 hydrocarbons, which can then be condensed and reintroduced as part or all of the deasphalting solvent at various locations within the solvent deasphalting process. For instance, the middle fraction can be combined with the bitumen-containing feedstock, and/or can be used as a clarifying solvent for the clarifying column. The middle

Date Reçue/Date Received 2021-01-08

fraction from the deasphalted oil/solvent separator can also be combined with the solvent recovered from the vapour-solid cyclone used to produce the recovered solvent stream and solid asphaltene precipitates.

[00115] The use of the middle fraction comprising C_5 to C_8 hydrocarbons produced by a stripping column as a deasphalting solvent can be beneficial in terms of availability, since this middle fraction can be produced locally within the deasphalting process. The use of the middle fraction comprising C_5 to C_8 hydrocarbons can also offer an opportunity to save costs by avoiding transportation of a deasphalting solvent, such as butane, propane, or pentane, from a remote location to on-site installations, and the cost of such deasphalting solvent itself. Separating diluent in a stripping column to produce a middle fraction comprising C_5 to C_8 hydrocarbons as deasphalting solvent can overcome certain challenges associated with using straight naphtha as deasphalting solvent, and can also enable the use of existing equipment for multiple purposes instead of having to dedicate an additional distillation column for recovering a pure deasphalting solvent, such as butane, propane, or pentane, thus lowering capital costs in some implementations.

[00116] In summary, the use of a centrifugal separation device and clarifying column according to the configuration described herein in the context of a solvent deasphalting process versus a gravity separation device can contribute to reducing the solvent inventory needed to separate asphaltene precipitates from the liquid deasphalted oil, and to improve the deasphalted oil removal from the asphaltene precipitates down to less than about 15 wt%, and in some implementation, to even less then about 7 wt% when an additional separation step for removing residual solvent is implemented. The amount of deasphalting solvent that is used to achieve such results is reduced, which in turn contributes to decreasing the size of the equipment. Operating costs for the described solvent deasphalting process can thus also be reduced. In addition, the performance of a single hydrocyclone combined with a clarifying column can facilitate higher yields of deasphalted oil than known commercial solvent deasphalting processes.

[00117] Various techniques and systems will now be described for solvent deasphalting a bitumen-containing feedstock.

Date Reçue/Date Received 2021-01-08

General overview of solvent deasphalting process

[00118] Referring to Figure 1, an example of a deasphalting process 10 is illustrated. The deasphalting process 10 includes combining a bitumen-containing feedstock 12 with a deasphalting solvent 14 in a mixing unit 16.

[00119] The bitumen-containing feedstock 12 can include or be various types of bitumen streams. For instance, the bitumen-containing feedstock 12 can include bitumen that was extracted from a bitumen-bearing subterranean formation using an *in situ* recovery process, *e.g.*, a thermal energy-based recovery method such as steam assisted gravity drainage (SAGD) or cyclic steam stimulation (CSS), a solvent-based recovery method such as *in situ* solvent or solvent-steam extraction, an *in situ* combustion recovery method, a cold production process, an electromagnetic energy assisted process, or a concurrent or sequential combination thereof.

[00120] The bitumen-containing feedstock can also include bitumen extracted from oil sands ore using surface mining operations. In such operations, oil sands ore is mined, followed by crushing and sizing of the ore to produce a sized material that can be mixed with warm or hot water to obtain an oil sands slurry suitable for hydrotransport. At this stage, the oil sands slurry can also be subjected to various forms of conditioning to improve its properties. The hydrotransport can also provide a pipeline connection between mining operations and primary extraction operations. The primary extraction is performed to separate the oil sands slurry into a bitumen froth and tailings. The bitumen froth is then subjected to secondary extraction, which can also be referred to as froth treatment, to separate the bitumen from solids and water. In froth treatment, a solvent or diluent is added to the froth to aid separation to produce a bitumen enriched material and froth treatment tailings. The bitumen enriched material from froth treatment is an example of a bitumen-containing feedstock suitable for the solvent deasphalting process 10 described herein.

[00121] In some implementations, the bitumen-containing feedstock may have been subjected to a pre-treatment prior to being subjected to the solvent deasphalting process 10. For instance, the bitumen stream can be subjected to a thermal treatment before solvent deasphalting. The thermal treatment can be a low-intensity thermal treatment

Date Reçue/Date Received 2021-01-08

aimed at reducing the viscosity of the bitumen stream. The thermal treatment can also be performed at higher severity conditions to induce thermal cracking of large molecular weight hydrocarbons into smaller molecular weight molecules. When the pre-treatment includes thermal cracking of bitumen, such thermal cracking can be operated to produce a single output of a thermally treated bitumen stream that can be directly used as the suitable bitumen-containing feedstock for subsequent solvent deasphalting. Alternatively, the thermal treatment can be operated to produce a thermally-affected asphaltene-rich stream and a thermally-affected asphaltene-depleted stream. In such implementations, it can be beneficial to subject the thermally-affected asphaltene-rich stream to solvent deasphalting to precipitate and separate asphaltenes therefrom. On the other hand, the thermally-affected asphaltene-depleted stream can also be subjected to a solvent deasphalting process as described herein to further remove asphaltenes therefrom, if present.

[00122] The bitumen-containing feedstock can also be a heavy fraction obtained from whole bitumen that has undergone fractionation or distillation to remove light hydrocarbon components therefrom. The heavy fraction, which can also be called a vacuum fraction in some cases, can be subjected to a pre-treatment, such as a thermal treatment, to either produce a thermally affected heavy fraction as a single output stream, or produce a thermally-affected asphaltene-rich stream and a thermally-affected asphaltene-depleted stream. Any one of the thermally affected heavy fraction, the thermally-affected asphaltene-rich stream or the thermally-affected asphaltene-depleted stream can be suitable bitumen-containing streams for the solvent deasphalting process described herein. Alternatively, the heavy fraction can be subjected directly to the solvent deasphalting process as described herein.

[00123] The bitumen-containing feedstock can also be a blend of two or more bitumen streams. The bitumen included in the bitumen-containing feedstock can also come from any other suitable source, such as *in situ* processes, surface mining processes, bitumen recovery from tailings or other waste materials, and so on.

[00124] The deasphalting solvent 14 can be any suitable solvent that enables precipitation of asphaltenes present in the bitumen-containing feedstock 12, thereby forming asphaltene precipitates, while dissolving the remainder of the bitumen-containing feedstock 12. Formation of such asphaltene precipitates can allow for a subsequent selective separation of the components of the bitumen-containing feedstock 12 according to their solubility properties, and thus to reject heavier components such as the asphaltene precipitates. Examples of suitable solvents can include alkane-based solvents, such as propane, butane, pentane, hexane, heptane, or octane, or a combination thereof; branched hydrocarbons, such as isopentane; and hydrocarbons that include cyclic structures, such as cyclopentane and cyclohexane. Diluents, such as naphtha, and other cuts can also be used as a deasphalting solvent since they can include certain hydrocarbon fractions that can precipitate asphaltenes at appropriate solvent-to-bitumen ratios and other operating conditions.

[00125] In some implementations, the deasphalting solvent 14 can be supplied as fresh deasphalting solvent 20 when combined with the bitumen-containing feedstock 12. The deasphalting solvent 14 can also be provided as a recycled deasphalting solvent 20 that is recovered from certain parts of the solvent deasphalting process 10, as will be described in further detail below. In some implementations, the fresh deasphalting solvent 20 and the recycled deasphalting solvent 22 can be combined to form the deasphalting solvent 14, and can be supplied from a deasphalting solvent supply 18. In other implementations, either one the of fresh deasphalting solvent 20 and the recycled deasphalting solvent 22 can be provided as standalone solvent to act as the deasphalting solvent 14 for combination with the bitumen-containing feedstock 12.

[00126] Combining the bitumen-containing feedstock 12 with the deasphalting solvent 14 produces a diluted bitumen stream 24 that includes asphaltene precipitates in suspension in deasphalted oil. The bitumen-containing feedstock 12 and the deasphalting solvent 14 can be contacted and mixed in various ways, some of which will be described in further detail below.

[00127] The mixing unit 16 used to combine the bitumen-containing feedstock 12 with the deasphalting solvent 14 can be any type of mixing device that enables contacting of the deasphalting solvent 14 with the bitumen-containing feedstock 12 such that formation of asphaltene precipitates can be initiated upon or following contact between the bitumen-containing feedstock 12 and the deasphalting solvent 14. Mixing devices that can be suitable include for instance static mixers, shear mixers and mixing tees. The choice of

Date Reçue/Date Received 2021-01-08

mixing device can depend on the characteristics of the bitumen-containing feedstock 12 that is to be contacted with the deasphalting solvent 14, among others. In some implementations, the use of a mixing tee having a particular configuration can be beneficial to enhance the mixing the bitumen-containing feedstock 12 with the deasphalting solvent 14.

[00128] With reference to Figure 2, an example of a mixing tee 100 having a particular configuration to achieve rapid mixing of a bitumen-containing feedstock 12 and a deasphalting solvent 14 is shown. In this implementation, the mixing tee 100 includes a pipeline section 101 that includes a feedstock section 102 and a solvent section 104. The feedstock section 102 and the solvent section 104 intersect at a junction 107 from which extends a diluted bitumen section 108, or output section. As shown in Figure 2, the diluted bitumen section 108 extends at an angle with respect to the longitudinal axis of the pipeline section 101, to form the "tee" shape of the mixing tee. Although in the implementation shown in Figure 2, the diluted bitumen section 108 extends substantially perpendicularly from the pipeline section 101, the diluted bitumen section 108 can be provided at other various angles in relation to the longitudinal axis of the pipeline section 101. For instance, the diluted bitumen section 108 can extend at an angle ranging from 45° to 90° relative to the longitudinal axis of the pipeline section 101.

[00129] In the illustrated implementation, the mixing tee 100 is configured such that the bitumen-containing feedstock 12 flowing in one direction in the feedstock section 102 contacts or collides with the deasphalting solvent 14 flowing in an opposite direction in the solvent section 104 when meeting in a mixing zone 106 located at the junction 107 of the feedstock section 102 and the solvent section 104. The contacting of the bitumen-containing feedstock 12 and the deasphalting solvent 14 forms the diluted bitumen stream 24 that comprises deasphalted oil and asphaltene precipitates. When the bitumen-containing feedstock 12 collides with the deasphalting solvent 14, formation of asphaltene precipitates 110 can be initiated, and the asphaltene precipitates 110 can be carried into the diluted bitumen section 108.

[00130] In some implementations, the velocity of the deasphalting solvent 14 within the solvent section 104 can be higher that the velocity of the bitumen-containing feedstock 12 within the bitumen-containing pipeline section 102 to facilitate penetration of the

Date Reçue/Date Received 2021-01-08

deasphalting solvent 14 into the bitumen-containing feedstock 12. For instance, in some implementations, the velocity of the bitumen-containing feedstock 12 within the bitumen-containing pipeline section 102 can range from about 1 cm/s to about 5 cm/s, while the velocity of the deasphalting solvent 14 within the solvent section 104 can range from about 90 cm/s to about 150 cm/s.

[00131] In some implementations, the turbulence of the deasphalting solvent 14 within the solvent section 104 can be higher than the turbulence of the bitumen-containing feedstock 12 within the bitumen-containing pipeline section 102 to facilitate penetration of the deasphalting solvent 14 into the bitumen-containing feedstock 12. For instance, in some implementations, the Reynolds number of the deasphalting solvent 14 within the solvent section 104 can be above about 4000, while the Reynolds number of the bitumen-containing feedstock 12 within the bitumen-containing pipeline section 102 can be above about 200. In some scenarios, the Reynolds number of the deasphalting solvent 14 within the solvent section 104 can range from about 30 000 to 35 000. In some scenarios, the Reynolds number of the bitumen-containing feedstock 12 within the bitumen-containing pipeline section 102 can range from about 2000 to 5000.

[00132] In addition, the temperature of the bitumen-containing feedstock 12 and the deasphalting solvent 14 can be modulated to reduce their respective viscosity to facilitate penetration of the deasphalting solvent 14 into the bitumen-containing feedstock 12. For instance, the temperature of the bitumen-containing feedstock 12 can be increased to reduce its viscosity, and the temperature of the deasphalting solvent 14 can also be increased to reduce its viscosity. In some scenarios, the viscosity of the bitumen-containing feedstock can be below about 1000 cSt, or below about 200 cSt.

[00133] In some implementations, the solvent section 104 can include a valve 112, such as a pressure reduction valve. Any type of valve that can provide a pressure drop in the range of about 20 psi to about 40 psi can be suitable for installation on the solvent section 104. The valve 112 can be operated so as to increase the momentum of the deasphalting solvent 14 into the bitumen-containing feedstock 12 when the deasphalting solvent 14 collides into the bitumen-containing feedstock 12 in the mixing zone 106, thereby facilitating the penetration of the deasphalting solvent 14 into the bitumen-containing feedstock 12. More particularly, the valve can enable the conversion of potential energy

Date Reçue/Date Received 2021-01-08

that is in the form of pressure to kinetic energy as the deasphalted solvent 14 is accelerated through the opening of the valve, which has a smaller opening than the diameter of the solvent section 104. The acceleration of the deasphalting solvent 14 into the oncoming bitumen-containing feedstock can facilitate the penetration of the deasphalting solvent 14 into the bitumen-containing feedstock 12, which in turn can enable surrounding the asphaltene molecules with solvent to facilitate their coming out of solution, *i.e.*, their precipitation. In other words, one of the objectives of using a valve 112 is to drop pressure enough to accelerate the deasphalting solvent 14 fast enough to comingle, or mix, with the bitumen-containing feedstock 12.

[00134] In some implementations, increasing the momentum and the force with which the deasphalting solvent 14 penetrates into the bitumen-containing feedstock 12 contributes to avoid or reduce formation of a biphasic mixture that may impair the formation of asphaltene precipitates. Increasing the momentum and the force with which the deasphalting solvent 14 penetrates into the bitumen-containing feedstock 12 can also contribute to impart rapid mixing of the bitumen-containing feedstock 12 and the deasphalting solvent 14.

[00135] Still referring to Figure 2, the feedstock section 102 and the solvent section 104 can be sized to facilitate the penetration of the deasphalting solvent 14 into the bitumen-containing feedstock 12. For instance, in some implementations, the diameter of the solvent section 104 can be smaller than the diameter of the feedstock section 102 to achieve a higher velocity of the deasphalting solvent within the solvent section 104, for a similar flowrate. A solvent section 104 having a smaller diameter can contribute to generating a higher pressure drop, enabling the loss of potential energy to be converted to kinetic energy. For instance, in some implementations, the ratio of the diameter of the solvent section 104 relative to the diameter of the feedstock section 102, or relative to the diameter of the diluted bitumen section 108, can range from about 0.3 to about 0.7.

[00136] The feedstock section 102 and the solvent section 104 can be provided along a same longitudinal axis, such as shown in Figure 2. In other words, the feedstock section 102 and the solvent section 104 can be provided at a 180° relative to each other. In other implementations, the feedstock section 102 and the solvent section 104 can be provided at an angle that is larger than 180° or smaller than 180° relative to each other. For

Date Reçue/Date Received 2021-01-08

instance, the feedstock section 102 and the solvent section 104 can form a "V" shape or a "A" shape.

[00137] As mentioned above, the mixing tee 100 is configured such that the bitumen-containing feedstock 12 flowing in one direction in the feedstock section 102 contacts or collides with the deasphalting solvent 14 flowing in an opposite direction in the solvent section 104 when meeting in a mixing zone 106. It is to be understood that when referring to bitumen-containing feedstock 12 flowing in one direction in the feedstock section 102 contacts or collides with the deasphalting solvent 14 flowing in an opposite direction, at least one directional component is directly opposite. Thus, in implementations where the feedstock section 102 and the solvent section 104 are provided at an angle different than 180°, at least one component of the directions is directly opposite.

[00138] As mentioned above, referring to Figs 1 and 3, combining the bitumen-containing feedstock 12 with the deasphalting solvent 14 produces a diluted bitumen stream 24 comprising deasphalted oil and asphaltene precipitates in suspension in deasphalted oil. The diluted bitumen stream 24 is transported via feed pipeline to a centrifugal separation device 26. The feed pipeline can have various configurations and dimensions in terms of length and diameter. Since at this stage of the deasphalting process, asphaltene precipitates have started to form, it may be desirable to transport the diluted bitumen stream 24 along a feed pipeline that is sized and configured to avoid settling of the asphaltene precipitates therein. The feed pipeline can also be sized and configured such that the diluted bitumen stream 24 travels under a turbulent regime rather than a laminar regime that could undesirably favor the settling of the asphaltene precipitates. The pipeline can further be sized and configured such that additional asphaltene precipitates can form during transportation.

[00139] In some implementations, the diluted bitumen stream 24 can be heated to reduce the viscosity of the diluted bitumen stream 24 and facilitate flowing thereof within the feed pipeline. Heating the diluted bitumen stream 24 can also facilitate the operation of the centrifugal separation device 26. For instance, the diluted bitumen stream 24 can be heated to a temperature ranging from about 50°C to about 10°C below the critical point of the deasphalting solvent 14 that is used. It is to be noted that heating can also be provided upstream of the mixing unit 16 to heat the bitumen-containing feedstock 12 and/or to heat

Date Reçue/Date Received 2021-01-08

the deasphalting solvent 14 prior to their combination. Heating the bitumen-containing feedstock 12 can facilitate its transportation and flow within the pipeline leading to the mixing unit 16, and facilitate mixing with the deasphalting solvent 14.

[00140] The centrifugal separation device 26, which can include a hydrocyclone that is configured to separate solids components contained in the diluted bitumen stream 24 from the liquid portion thereof, via centrifugal mechanisms, *i.e.*, based on the differences in density of the components in the diluted bitumen stream 24. In other words, the centrifugal separation device 26 is configured to separate the asphaltene precipitates from the deasphalted oil and deasphalting solvent present in the diluted bitumen stream 24. In some implementations, additional precipitation of asphaltenes can also occur within the centrifugal separation device 26. During operation, a portion of the deasphalting solvent 14 and the deasphalted oil travels towards the top of the centrifugal separation device 26, while the asphaltene precipitates tend to travel outwardly and then downwardly, towards the bottom of the centrifugal separation device 26. The centrifugal separation device 26 thus produces an overflow stream 28 that includes deasphalted oil that is diluted in deasphalting solvent, and an underflow stream 30 that includes asphaltene precipitates, residual deasphalting solvent, and residual deasphalted oil.

[00141] It is noted that the expression “asphaltene precipitates” as used herein refers to the formation of aggregates composed mainly of asphaltenes, and that may contain various amounts of resins. The amount of resins adhered to the asphaltene precipitates can influence the consistency of the asphaltene precipitates, which can range for instance from a sticky consistency to a substantially dry consistency once separated from deasphalting solvent and deasphalted oil. In some implementations, the asphaltene precipitates can be considered as dry asphaltene precipitates, for instance when the resin content of the asphaltene precipitates is below about 15 wt%. Another way to characterize the asphaltene precipitates is according to their softening point. For instance, asphaltene precipitates having a softening point above pyrolysis temperature at atmospheric pressure, or at operating conditions, can be considered as solid asphaltene precipitates.

[00142] In some implementations, solid asphaltene precipitates can form upon mixing of the bitumen-containing feedstock 12 and the deasphalting solvent 14 in the mixing unit 16, *i.e.*, asphaltene precipitates having a softening point above pyrolysis temperature at

Date Reçue/Date Received 2021-01-08

atmospheric pressure, or at operating conditions. Forming solid asphaltene precipitates upstream of the centrifugal separation device 26 can facilitate their separation from the liquid portion of the diluted bitumen stream 24, given the higher difference in densities between solids and liquids. In some implementations, the solid asphaltene precipitates can have a diameter that ranges from about 10 µm to about 240 µm. In some implementations, the range of diameters of the solid asphaltene precipitates can extend from 0.375 µm to 2000 µm.

[00143] The proportion of deasphalting solvent 14 relative to the bitumen-containing feedstock 12, which can be referred to as a solvent-to-oil ratio (SOR) or solvent-to-bitumen ratio (SBR), when these two streams are combined prior to being subjected to centrifugal separation in the centrifugal separation device 26 can vary and can be optimized to achieve a certain composition of the output streams produced during the solvent deasphalting process 10. For example, in some implementations, the SOR on a mass basis can range from about 1.5 to 6, from about 2 to about 5, or from about 2.5 to about 4. A higher SOR generally results in a higher recovery of deasphalted oil in the overflow stream 28, but this higher demand in deasphalting solvent generally has to be balanced with economic considerations associated with a higher solvent usage

[00144] The centrifugal separation device 26 can be operated at a temperature that facilitates separation of the asphaltene precipitates from the diluted bitumen stream 24. The temperature at which is operated the centrifugal separation device 26 can range for instance from about 50°C to about 10°C, from about 40°C to about 20°C, or from about 30°C to about 20°C, below the critical point of the deasphalting solvent 14 used, and at a pressure ranging from about 1200 kPa to about 3000 kPa. For instance, in some implementations, the centrifugal separation device 26 can be operated at a temperature ranging from about 100°C to about 250°C, or from about 120°C to about 220°C.

[00145] The residence time of the diluted bitumen stream 24 within the centrifugal separation device 26 can vary depending on the composition of the diluted bitumen stream 24, which in turn can depend on the deasphalting solvent 14 used and the type of bitumen-containing feedstock 12 subjected to the solvent deasphalting process 10. In some implementations, the residence time of the diluted bitumen stream 24 in the centrifugal separation device 26 can range from about 5 seconds to about 120 seconds, or from about

Date Reçue/Date Received 2021-01-08

10 seconds to about 60 seconds. Longer residence time than 120 seconds can also be envisioned.

[00146] The overflow stream 28 containing deasphalted oil that is diluted in deasphalting solvent can then be subjected to separation to recover deasphalting solvent therefrom and to produce a deasphalted oil product. Depending on the deasphalting solvent 14 used, the recovered deasphalting solvent can be re-used in the solvent deasphalting process. Additional details regarding the separation of the deasphalted oil diluted in deasphalting solvent are provided below.

[00147] As mentioned above, the underflow stream 30 from the centrifugal separation device 26 includes asphaltene precipitates that are diluted in residual deasphalting solvent and residual deasphalted oil. The resins from the residual deasphalted oil enable asphaltene precipitates to agglomerate and form larger precipitates compared to when smaller amounts of resins would be present. In some implementations, the centrifugal separation device 26 can produce an underflow stream 30 that includes less than about 40 wt%, between about 20 wt% to about 35 wt%, between about 25 wt% to about 30 wt%, of deasphalted oil, or less than about 15 wt%.

[00148] In some implementations, the combination of the temperature and pressure at which is operated the centrifugal separation device 26 and the choice and amount of deasphalting solvent used can enable additional formation of asphaltene precipitates, which can facilitate their separation from deasphalted oil and deasphalting solvent in the centrifugal separation device 26.

[00149] The centrifugal separation device 26 can have various configurations and sizes. For example, the centrifugal separation device 26 can be a vertical hydrocyclone, or any other type of centrifugal device. When the centrifugal separation device 26 includes a hydrocyclone, the operation of the hydrocyclone can be performed so as to achieve a given pressure differential ratio (PDR). The PDR is a relationship between the pressure at the inlet of the hydrocyclone, a pressure of the underflow, and a pressure of the overflow, as follows:

$$PDR = \frac{(Pressure\ at\ inlet - Pressure\ of\ the\ overflow)}{(Pressure\ at\ inlet - Pressure\ of\ the\ underflow)}$$

Date Reçue/Date Received 2021-01-08

[00150] In some implementations, the hydrocyclone can be operated such that the PDR is above about 2, or between about 2 and about 10. In some scenarios, a higher PDR can translate in a reduced amount of asphaltene precipitates in the overflow stream 28 of the hydrocyclone. In some implementations, the pressure at the inlet of the hydrocyclone can range from between about 350 psi to about 550 psi, the pressure of the overflow of the hydrocyclone can range from between 350 psi to about 550 psi, and the pressure of the overflow of the hydrocyclone can range from between 350 psi to about 450 psi. The operating pressure of the hydrocyclone can be determined such that the pressure is above the deasphalting solvent flash pressure at given operating temperature and below the critical point of the deasphalting solvent used to keep the deasphalting solvent in liquid phase.

[00151] The underflow stream 30 from the centrifugal separation device 26 is then transported, for instance via pipeline, to a clarifying column 32 that is configured to produce a solvent fraction 36 that is enriched in solvent and depleted in asphaltene precipitates and that can also include residual deasphalted oil, and an asphaltenes fraction 38 that is enriched in asphaltene precipitates.

[00152] Similarly to the considerations mentioned above regarding the transportation of the diluted bitumen stream 24 comprising the bitumen-containing feedstock 12 and the deasphalting solvent 14 to the centrifugal separation device 26, the pipeline transporting the underflow stream 30 to the clarifying column 32 can have various configuration and dimensions in terms of length and diameter. Since the diluted bitumen stream 24 comprises asphaltene precipitates diluted in deasphalted oil and deasphalting solvent 14, it may be desirable to transport the diluted bitumen stream 24 along a pipeline that is sized and configured to avoid settling of the asphaltene precipitates therein. The pipeline can also be sized and configured such that the diluted bitumen stream 24 travels under a turbulent regime rather than a laminar regime that would undesirably favor the settling of the asphaltene precipitates. The pipeline can further be sized and configured such that additional asphaltene precipitates can form during transportation.

[00153] The clarifying column 32 is configured to receive the underflow stream 30 in an upper portion thereof, and a clarifying solvent 34 in a lower portion thereof. The clarifying column 32 can thus include an inlet for receiving the underflow stream 30 from the

Date Reçue/Date Received 2021-01-08

centrifugal separation device 26, which can be located in an upper portion of the clarifying column 32, and an inlet for receiving the clarifying solvent 34, which can be located in a lower portion of the clarifying column 32. The clarifying column 32 also includes an outlet for retrieving the asphaltenes fraction 38, and an outlet for retrieving the solvent fraction 36.

[00154] In some implementations, the clarifying column 32 can be operated at a temperature of between about 40°C and about 50°C, or between about 20°C and about 40°C, below the critical point of the deasphalting solvent 14 used. The operating temperature of the clarifying column 32 can be determined so as to keep the deasphalting solvent 14 in liquid phase. The operating temperature of the clarifying column 32 can also be determined so as to improve the absorptive force of the deasphalting solvent for the deasphalted oil away from the precipitated asphaltenes, which can contribute to reduce the amount of deasphalting solvent for operating the clarifying column 32. The clarifying column 32 can be operated at a pressure that is lower than the operating pressure of the centrifugal separation device 26 to create a driving force to transport the underflow stream 30 from the centrifugal separation device 26 to the clarifying column 32. In some implementations, the clarifying column 32 can be operated at a pressure ranging from about 300 psi to about 500 psi.

[00155] The clarifying column 32 is configured for washing the asphaltene precipitates included in the underflow stream 30 with the clarifying solvent 34 to remove deasphalted oil that may surround the asphaltene precipitates and that may lead to undesired agglomeration, and to improve deasphalted oil recovery. During operation, the underflow stream 30 settles downwardly by gravity towards the bottom of the clarifying column 32 while the clarifying solvent stream 34 flows upwardly towards the top of the clarifying column 32. The clarifying column 32 thus operates in a counter-current fashion to further remove deasphalted oil from the asphaltene precipitates.

[00156] The residence time of the underflow stream 30 within the clarifying column 32 can vary depending on the deasphalting solvent 14 used and the type of bitumen-containing feedstock 12 subjected to the solvent deasphalting process 10. In some implementations, the residence time of the underflow stream 30 in the clarifying column 32 can range from

Date Reçue/Date Received 2021-01-08

about 5 minutes to about 60 minutes, or from about 10 minutes to about 30 minutes. Longer residence time than an hour can also be envisioned.

[00157] As mentioned above, the solvent fraction 36 is enriched in solvent and depleted in asphaltene precipitates. The solvent fraction 36 also includes residual deasphalted oil removed from the asphaltene precipitates due to the counter-current flow of the clarifying solvent. The solvent fraction 36 can thus also be considered a solvent-rich deasphalted oil fraction, or a deasphalted oil-rich solvent fraction. The asphaltenes fraction 38 can also include residual deasphalted oil. For instance, in some implementations, the residual deasphalted oil in the asphaltenes fraction 38 can range between about 15 wt% and about 20 wt%, between about 10 wt% and about 15 wt%, or between about 5 wt% and about 10 wt%. In some implementations, the residual deasphalted oil in the asphaltenes fraction 38 can be less than about 7 wt%.

[00158] The percentage of residual deasphalted oil in the asphaltenes fraction 38 can be influenced by the ratio of clarifying solvent 34 used for the operation of the clarifying column 32 relative to the underflow stream 30, with the more solvent used typically resulting in a lower concentration of residual deasphalted oil in the asphaltenes fraction 38. For example, in some implementations, the SOR on a mass basis for the clarifying solvent 34 relative to the underflow stream 30 can range from about 1 to 15, from about 2 to about 13, or from about 2.5 to about 11. As mentioned above with regard to the operation of the centrifugal separation device 26, a higher SOR for operation of the clarifying column 32 can generally translate in a higher recovery of deasphalted oil in the solvent fraction 26, but this higher demand in clarifying solvent generally also has to be balanced with economic considerations associated with a higher solvent usage. The choice of the SOR for the centrifugal separation device 26 and the SOR for the clarifying column 32 can also be interrelated to achieve a given deasphalted oil recovery above a certain threshold. In some implementations, the SOR for the centrifugal separation device 26 and the SOR for the clarifying column 32 can be such that the recovery of deasphalted oil is above about 85 wt%, above about 90 wt%, above about 95 wt%, or above about 98 wt%.

Date Reçue/Date Received 2021-01-08

[00159] In some implementations, the solvent fraction 36 exiting the clarifying column 32 can optionnaly be cooled down to obtain the recycled deasphalting solvent 22 that can be used as the deasphalting solvent 14 for mixing with the bitumen-containing feedstock 12.

[00160] The asphaltenes fraction 38 can optionally be subjected to an additional separation step to further recover solvent therefrom. Accordingly, the asphaltenes fraction 38, which includes asphaltene precipitates, residual solvent and is substantially free of deasphalted oil, can be transported via pipeline to a vapour-solid separation device 40, which can be a cyclone, where solvent vapour is separated from asphaltene precipitates. As used herein, the expression “substantially free of deasphalted oil” can refer to an asphaltenes fraction 38 that includes less than about 15 wt% of deasphalted oil, although in some implementations, the asphaltenes fraction 38 can include less than about 7 wt% of deasphalted oil. The vapour-solid separation device 40 produces a recovered vaporized solvent stream 44 and solid asphaltenes 46. In some implementations, the recovered vaporized solvent stream 44 can be condensed and recycled to various parts of the solvent deasphalting process 10, such as to the clarifying column 32.

[00161] As used herein, the expression “dry asphaltene precipitates” refers to asphaltene precipitates that have a deasphalted oil content of less than about 15 wt%. In some implementations, the dry asphaltene precipitates can have a powdery consistency, given the low content of deasphalted oil, or resins, contained therein. Such dry asphaltene precipitates can be suitable for use in various applications, such as to produce carbon fiber or activated carbon products. In accordance with what is mentioned above, an asphaltenes fraction 38 that is substantially free of deasphalted oil can thus be referred to as dry asphaltenes precipitates.

[00162] A back pressure valve 42 can be installed along the pipeline transporting the asphaltenes fraction 38 from the clarifying column 32 to the vapour-solid separation device 40 to flash residual solvent contained in the asphaltenes fraction 38 within the pipeline prior to entry into the vapour-solid separation device 40. The feed stream to the vapour-solid separation device 40, downstream of the clarifying column 32 can thus include vaporized residual solvent and asphaltene precipitates. The back pressure valve 42 can also enable the asphaltenes fraction 38 to be supplied to the vapour-solid separation device 40 at a given pressure, which can be determined such that performance of the

Date Reçue/Date Received 2021-01-08

vapour-solid separation device 40 operates to achieve a given level of separation of the vaporized solvent 44 from the solid asphaltenes 46.

[00163] In some implementations, the vaporized solvent 44 exiting the solid-liquid separation device 40 can subsequently be condensed to produce a liquid recovered solvent stream that can re-used in various parts of the solvent deasphalting process 10. For instance, the liquid recovered solvent can be suitable for use as the clarifying solvent 34 for the clarifying column 32, or as the deasphalting solvent 14 for mixing with the bitumen-containing feedstock 12.

[00164] Referring now to Figure 3, another example implementation of a solvent deasphalting process 10 will be described in further detail. It is to be noted that similar features as those illustrated in Figure 1 are represented with corresponding reference numbers in Figure 3. In this alternative implementation, the solvent deasphalting process 10 can be described as an integrated solvent deasphalting process that includes various separation steps enabling the recovery of a deasphalting solvent that can be re-used at various locations throughout the process, such as for mixing with the bitumen-containing feedstock and for introduction into the clarifying column.

[00165] The solvent deasphalting process 10 incudes combining a bitumen-containing feedstock 12 with a deasphalting solvent 14 in a mixing unit 16. The bitumen-containing feedstock 12 can be any type of bitumen streams as described above. The mixing unit 16 can include a static mixer, a shear mixer, or a mixing tee. The mixing tee can be a mixing tee as illustrated in Figure 2 and as described above, to achieve rapid and substantially instantaneous mixing of the bitumen-containing feedstock 12 with the deasphalting solvent 14.

[00166] The diluted bitumen stream 24 comprising deasphalted oil and asphaltene precipitates is then supplied to a centrifugal separation device 26 as described above, the centrifugal separation device producing an overflow stream 28 that includes deasphalted oil diluted in deasphalting solvent, and an underflow stream 30 that includes asphaltene precipitates, residual deasphalting solvent, and residual deasphalted oil.

Date Reçue/Date Received 2021-01-08

[00167] The underflow stream 38 from the clarifying column 32 is subsequently supplied to a vapour-solid separation device 40 that is configured to separate vaporized deasphalting solvent 44 from solid asphaltenes 46.

[00168] In this implementations of the integrated solvent deasphalting process, the overflow stream 28 from the centrifugal separation device 26 is supplied to a deasphalted oil/deasphalting solvent separator to separate deasphalted oil from the deasphalting solvent. The deasphalted oil/deasphalting solvent separator can be for instance a stripping column, or a solvent recovery unit (SRU). In the implementation illustrated in Figure 3, a stripping column 50 is shown as the deasphalted oil/deasphalting solvent separator.

[00169] The stripping column 50 is configured to receive a stripping fluid 62 such as steam or natural gas. The stripping fluid 62 can be injected into the stripping column 50 at conditions that facilitate stripping of a light fraction that includes hydrocarbons one to eight carbon atoms, *i.e.*, C_1 to C_8 hydrocarbons. In addition to receiving the overflow stream 28 and the stripping fluid 62 as input streams, the stripping column 50 can be configured to receive a diluent 52 from a make-up diluent supply 54. The diluent 52 can be for instance naphtha, which generally includes a mixture of hydrocarbons at least in the C_3 to C_{10} range, *i.e.*, hydrocarbons that contain 3 to 10 carbon atoms. Other diluents obtained from an upgrader facility and that includes various fractions of hydrocarbons, *i.e.*, hydrocarbons having three to ten carbon atoms, *i.e.*, C_3 to C_{10} hydrocarbons, can also be suitable diluents for the make-up diluent 52. In some implementations, less than about 10 wt%, less than about 8 wt%, less than about 5 wt%, or less than about 3 wt% of diluent 52 can be added to the stripping column 50. The stripping column 50 thus receives a mixture of deasphalting solvent and deasphalted oil from the overflow of the centrifugal separation device 26, diluent 52, and a stripping fluid 62. In some implementations, the diluent 52 can be replaced by a solvent, or a mixture of solvent and diluent can be added to the stripping column 50. Examples of solvents can include condensate, natural gas liquids, pentane, hexane, heptane, or any other solvent that contains a mix of C_4-C_{10} hydrocarbons.

[00170] In an implementation of the stripping column 50, the stripping column 50 includes a feed inlet for introducing the overflow stream 28 into the stripping column 50, a diluent inlet for introducing the make-up diluent 52 or solvent into the stripping column 50, and a vapor inlet for introducing a stripping fluid 62, such as natural gas or steam, into the

Date Reçue/Date Received 2021-01-08

stripping column 50. The stripping column 50 further includes an overhead outlet for retrieving the vapor overhead stream 56 that includes the stripping fluid 62 and stripped light hydrocarbons in the C_1 to C_8 range, and a deasphalted oil outlet to retrieve deasphalted oil 60 from the stripping column 50.

[00171] The stripping column 50 thus enables the removal of light hydrocarbons that are dissolved in the overflow stream 28 from the centrifugal separation device 26, and the production of a light fraction 56, or overhead stream, that can comprise light hydrocarbons such as C_1 to C_8 hydrocarbons via flashing. The light fraction 56 is then subjected to separation, for instance in a condenser, to remove non-condensable hydrocarbons in the C_1 to C_4 range as a lighter gas phase 57, from the hydrocarbons in the C_5 to C_8 range, which form a middle fraction 58. The stripping column 50 is further operated to produce a bottom fraction 60 that includes deasphalted oil recovered from the centrifugal separation device 26. In some implementations, the lighter gas phase 57 can be used as a component of fuel gas. The stripping column 50 can be operated at pressures near atmospheric pressures, such as between about 15 psia and 30 psia. The stripping column 50 can be operated at temperatures that enable flashing of the light fraction 56, such as between 90°C and 130°C. The middle fraction 58 can include various proportions of C_5 to C_8 hydrocarbons. For instance, in some implementations, C_5 can form from about 0 wt% to about 40 wt% of the middle fraction 58, C_6 and C_7 can be form from about 40 wt% to about 60 wt% of the middle fraction 58, and C_8 can be form from about 0 wt% to about 20 wt% of the middle fraction 58.

[00172] In other words, the stripping column 50 can be operated at conditions of temperature and pressure that enables flashing of the light fraction 56 comprising hydrocarbons in the C_1 to C_8 range due to the stripping action of the stripping fluid 62 to produce a vapor overhead that includes stripped hydrocarbons in the C_1 to C_8 range. The stripping column 50 also enables a heavy faction comprising C_9 hydrocarbons and above to report to the deasphalted oil. The light fraction 56 is then separated to produce the middle fraction 58 that comprises C_5 to C_8 hydrocarbons that is suitable for use as a deasphalting solvent in the remaining of the solvent deasphalting process. It is to be understood that when referring to the middle fraction 58 as a suitable deasphalting solvent,

Date Reçue/Date Received 2021-01-08

it is meant that the middle fraction 58 is suitable for acting as both the deasphalting solvent 14 and the clarifying solvent 34.

[00173] The operation of the stripping column 50 can be adapted depending on the make-up diluent 52 that is used to tailor the separation process in accordance with the composition of the make-up diluent 52.

[00174] The stripping column 50 can advantageously enable the use of existing equipment that is already in place to perform a separation of the deasphalting solvent from deasphalted oil while producing a middle fraction that is suitable for use as the deasphalting solvent 14. The middle fraction 58, *i.e.*, the condensed portion of the light fraction 56 produced as an overhead by the stripping column 50, can also be referred to as a diluent-derived deasphalting solvent. Diluent, such as naphtha, condensate, or a combination thereof, for use as make-up diluent 52 that is fed to the stripping column 50, is generally more readily available than pure deasphalting solvents such as propane, butane or pentane and also less costly. Although pure deasphalting solvents are generally performing well at precipitating asphaltenes present in bitumen, challenges related to their downstream separation from deasphalted oil can make these pure deasphalting solvents less attractive. In particular, when pure deasphalting solvents are used, an additional fractionation column or distillation column has to be installed to recover a specific fraction, such as a C_5 fraction, which can then be re-used at a deasphalting solvent. Fractionation columns and distillation columns are additional pieces of equipment that undesirably often have to be operated at critical conditions of temperature and pressure to perform the separation of specific and pure fractions of hydrocarbons, such as a C_5 fraction, according to their respective boiling points.

[00175] The middle fraction 58, which includes hydrocarbons in the C_5 to C_8 range, is suitable for use as a deasphalting solvent. A mixture of hydrocarbons in the C_5 to C_8 range can offer various advantages over pure deasphalting solvents such as propane and butane. For instance, using a deasphalting solvent that includes hydrocarbons in the C_5 to C_8 range can take advantage of the respective properties of each of these fractions. For instance, lighter hydrocarbons in a deasphalting solvent that includes hydrocarbons in the C_5 to C_8 range can facilitate separation of lighter components present in the underflow stream 30 when subjected to cleaning in the clarifying column 32. Lighter hydrocarbons in a deasphalting solvent that includes hydrocarbons in the C_5 to C_8 range can also facilitate precipitation of asphaltenes in the bitumen-containing feedstock 12 once contacted with the deasphalting solvent 14. Conversely, heavier hydrocarbons present in a deasphalting solvent that includes hydrocarbons in the C_5 to C_8 range can facilitate separation of heavier components present in the underflow stream 30 when subjected to cleaning in the clarifying column 32, for instance by absorbing and washing the deasphalted oil away from the asphaltenes precipitates, and can report to the asphaltenes fraction 38.

[00176] In some implementations, the middle fraction 58 can form a majority of the deasphalting solvent 14 as a diluent-derived deasphalting solvent. In such implementations, the proportion of deasphalting solvent 14 relative to the bitumen-containing feedstock 12 when these two streams are combined prior to being subjected to centrifugal separation in the centrifugal separation device 26 can vary and can be optimized to achieve a certain composition of the output streams produced during the solvent deasphalting process 10. For example and as mentioned above, the SOR on a mass basis can range from about 1.5 to 6, from about 2 to about 5, or from about 2.5 to about 4.

[00177] As mentioned above, the middle fraction 58, which includes hydrocarbons in the C_5 to C_8 range, is suitable for use as a deasphalting solvent. Once retrieved from the stripping column 50, the middle fraction 58 can be supplied to the clarifying column 50 to act as the clarifying solvent 34. As mentioned above, the clarifying solvent 34 can be introduced counter-currently in the clarifying column 32 to separate residual deasphalted oil from the underflow stream 30 produced by the centrifugal separation device 26. The resulting solvent fraction 36 enriched in deasphalted oil can then be supplied to directly to the mixing unit 16 to act as the deasphalting solvent 14, or can be supplied to the deasphalting solvent supply 18 where it can be combined with fresh deasphalting solvent 20 to obtain a deasphalting solvent 14 having desired properties. In some implementations, the solvent fraction 36 from the clarifying column 32 can be introduced in the stripping column 50 to contribute to the production of the various fractions produced by the operation of the stripping column 50.

[00178] A back pressure valve 43 can be installed along the pipeline transporting the overflow stream 28 to the stripping column 50 to vaporize at least a portion of a light

Date Reçue/Date Received 2021-01-08

fraction of the deasphalting solvent 14 along the pipeline. The back pressure valve 43 can also contribute to avoid pressure upsets within the centrifugal operation device 26. In order to do so, the top outlet of the centrifugal separation device 26 can be equipped with an orifice plate or similar restriction in cross-sectional surface area, which, conjointly with the operation of the back pressure valve 43, can prevent vapour generation in the centrifugal separation device 26 by maintaining the process pressure above the vaporization point of the deasphalting solvent at the operating temperature.

[00179] Still referring to Figure 3, the underflow stream 38 from the clarifying column 32 is supplied to the vapour-solid separation device 40, which produces the recovered vaporized solvent stream 44. The recovered vaporized solvent stream 44 can be supplied to a condenser 64 to produce a condensed recovered solvent 66. In some implementations, the condensed recovered solvent 66 can be recycled directly to the mixing unit 16 as the deasphalting solvent 14, or to the deasphalting solvent supply 18 to be combined with fresh deasphalting solvent 20 to obtain a deasphalting solvent 14 having desired properties. In other implementations, the condensed recovered solvent 66 can be supplied directly to the clarifying column 50 to act as the clarifying solvent 34. In yet other implementations, the condensed recovered solvent 66 can be combined with the middle fraction 58, or the condensed portion of the light fraction 56 from the stripping column 50 overhead, to produce a combined recovered solvent 68, which can be supplied to the clarifying column 32 to act as the clarifying solvent 34, or the combined recovered solvent 68 can be used as the deasphalting solvent 14.

[00180] In some implementations, the solvent fraction 36 from the clarifying column 32, which can contain residual deasphalted oil, can be supplied to the stripping column 50 to be subjected to separation and contribute to the production of the middle fraction 58. In such implementations, the residual deasphalting oil can advantageously report to the bottom of the stripping column 50 and form part of the deasphalted oil product 60.

[00181] It is to be noted that although the centrifugal separation device 26 has been illustrated as including a single hydrocyclone, the centrifugal separation device 26 can include more than one stage. For instance, two or more hydrocyclones can be provided in series to produce the underflow stream 30. Similarly, although the clarifying column 32 has been illustrated as including a single clarifying column, the clarifying column 32 can

Date Reçue/Date Received 2021-01-08

include more than one stage. For instance, two or more clarifying columns can be provided in series to produce the asphaltenes fraction 38. Yet again, although the vapour-solid separation device 40 has been illustrated as including a single cyclone, the vapour-solid separation device 40 can include more than one stage. For instance, two or more cyclones can be provided in series to produce the solid asphaltenes 46 and the vaporized solvent 44.

[00182] Several alternative implementations and examples have been described and illustrated herein. The implementations of the technology described above are intended to be exemplary only. A person of ordinary skill in the art would appreciate the features of the individual implementations, and the possible combinations and variations of the components. A person of ordinary skill in the art would further appreciate that any of the implementations could be provided in any combination with the other implementations disclosed herein. It is understood that the technology may be embodied in other specific forms without departing from the central characteristics thereof. The present implementations and examples, therefore, are to be considered in all respects as illustrative and not restrictive, and the technology is not to be limited to the details given herein. Accordingly, while the specific implementations have been illustrated and described, numerous modifications come to mind.

Date Reçue/Date Received 2021-01-08

CLAIMS

1. A process for treating a bitumen-containing feedstock, comprising:

    solvent deasphalting the bitumen-containing feedstock, comprising:

        contacting the bitumen-containing feedstock with a deasphalting solvent to induce precipitation of asphaltenes contained in the bitumen-containing feedstock and produce a diluted bitumen stream comprising deasphalted oil and asphaltene precipitates; and

        subjecting the diluted bitumen stream to centrifugal separation in a centrifugal separation device to recover an overflow stream comprising diluted deasphalted oil and an underflow stream comprising the asphaltene precipitates and residual deasphalting solvent; and

    subjecting the underflow stream from the centrifugal separation device to separation in a clarifying column to produce a solvent fraction enriched in solvent and depleted in asphaltene precipitates, and an asphaltenes fraction enriched in asphaltene precipitates.

2. The process of claim 1, wherein the centrifugal separation device comprises one or more hydrocyclones.

3. The process of claim 1 or 2, wherein the centrifugal separation device is operated at a temperature ranging from about 50°C to about 10°C below a critical point of the deasphalting solvent.

4. The process of any one of claims 1 to 3, wherein the centrifugal separation device is operated at a temperature ranging from about 40°C to about 20°C below a critical point of the deasphalting solvent.

5. The process of any one of claims 1 to 4, wherein the centrifugal separation device is operated at a temperature ranging from about 100°C to about 250°C.

Date Reçue/Date Received 2021-01-08

6. The process of any one of claims 1 to 5, wherein the centrifugal separation device is operated at a temperature ranging from about 120°C to about 220°C.

7. The process of any one of claims 1 to 6, wherein the centrifugal separation device is operated at a pressure ranging from about 1200 kPa to about 3000 kPa.

8. The process of any one of claims 1 to 7, wherein the asphaltenes precipitates have a softening point above pyrolysis temperature at operating conditions of the centrifugal separation device.

9. The process of any one of claims 1 to 8, wherein the contacting of the bitumen-containing feedstock with the deasphalting solvent is performed using a mixing device.

10. The process of claim 9, wherein the mixing device comprises at least one of a static mixer, a shear mixer, and a mixing tee.

11. The process of claim 9 or 10, wherein the mixing device comprises a mixing tee.

12. The process of claim 11, wherein the mixing tee comprises a feedstock section within which flows the bitumen-containing feedstock and a solvent section within which flows the deasphalting solvent, the solvent section being in fluid communication with the feedstock section.

13. The process of claim 12, wherein the feedstock section and the solvent section are provided at an angle ranging from about 170° to about 190° relative to each other.

14. The process of claim 12, wherein contacting the bitumen-containing feedstock with the deasphalting solvent comprises:

flowing the bitumen-containing feedstock in a first direction within the feedstock section; and

flowing the deasphalting solvent in a second direction within the solvent section, the second direction comprising at least one directional component opposite to the first direction, such that the bitumen-containing feedstock and

Date Reçue/Date Received 2021-01-08

the deasphalting solvent collide in a mixing zone to form the diluted bitumen stream and initiate formation of the asphaltene precipitates.

15. The process of any one of claims 12 to 14, wherein the mixing tee further comprises an output section within which flows the diluted bitumen stream.

16. The process of claim 14 or 15, wherein the solvent section comprises a valve operable to increase a velocity at which the deasphalting solvent collides into the bitumen-containing feedstock in the mixing zone.

17. The process of any one of claims 14 to 16, wherein the bitumen-containing feedstock is flowed in the first direction within the feedstock section at a Reynolds number above about 200.

18. The process of any one of claims 14 to 17, wherein the bitumen-containing feedstock is flowed in the first direction within the feedstock section at a Reynolds number ranging from about 2000 to about 5000.

19. The process of any one of claims 14 to 18, wherein the deasphalting solvent is flowed in the second direction within the solvent section at a Reynolds number above about 4000.

20. The process of any one of claims 14 to 19, wherein the deasphalting solvent is flowed in the second direction within the solvent section at a Reynolds number ranging from about 30 000 to about 35 000.

21. The process of any one of claims 1 to 20, wherein the asphaltene precipitates of the underflow stream from the centrifugal separation device comprise less than about 40 wt% of residual deasphalted oil.

22. The process of any one of claims 1 to 20, wherein the asphaltene precipitates of the underflow stream from the centrifugal separation device comprise between about 20 wt% and 35 wt% of residual deasphalted oil.

Date Reçue/Date Received 2021-01-08

23. The process of any one of claims 1 to 20, wherein the asphaltene precipitates of the underflow stream from the centrifugal separation device comprise between about 25 wt% and 30 wt% of residual deasphalted oil.

24. The process of any one of claims 1 to 23, wherein the deasphalting solvent comprises an alkane-based solvent.

25. The process of claim 24, wherein the alkane-based solvent comprises at least one of propane, butane, pentane, hexane heptane, and octane, or a combination thereof.

26. The process of any one of claims 1 to 25, wherein the deasphalting solvent comprises branched hydrocarbons.

27. The process of claim 26, wherein the branched hydrocarbons comprises isopentane.

28. The process of any one of claim 1 to 27, wherein the deasphalting solvent comprises hydrocarbons having cyclic structures.

29. The process of claim 28, wherein the hydrocarbons having cyclic structures comprises as least one of cyclopentane and cyclohexane.

30. The process of any one of claims 1 to 29, further comprising subjecting the overflow stream from the centrifugal separation device to separation in a deasphalted oil/solvent separator.

31. The process of claim 30, wherein the deasphalted oil/solvent separator is a stripping unit.

32. The process of claim 30 or 31, wherein subjecting the overflow stream from the centrifugal separation device to separation in the deasphalted oil/solvent separator comprises introducing a stripping fluid into the deasphalted oil/solvent separator.

33. The process of claim 32, wherein the stripping fluid comprises at least one of natural gas and steam.

Date Reçue/Date Received 2021-01-08

34. The process of any one of claim 30 to 33, wherein subjecting the overflow stream from the centrifugal separation device to separation in the deasphalted oil/solvent separator comprises adding a solvent to the deasphalted oil/solvent separator.

35. The process of any one of claim 30 to 33, wherein subjecting the overflow stream from the centrifugal separation device to separation in the deasphalted oil/solvent separator comprises adding a diluent to the deasphalted oil/solvent separator.

36. The process of claim 35, wherein the diluent comprises at least one of naphtha or condensate.

37. The process of any one of claims 30 to 36, wherein subjecting the overflow stream from the centrifugal separation device to separation in the deasphalted oil/solvent separator comprises flashing a light fraction comprising C_1 to C_8 hydrocarbons.

38. The process of any one of claims 30 to 37, wherein subjecting the overflow stream from the centrifugal separation device to separation in the deasphalted oil/solvent separator comprises producing a bottom fraction comprising deasphalted oil.

39. The process of claim 37, further comprising separating the light fraction from the deasphalted oil/solvent separator to produce a lighter fraction comprising C_1 to C_4 hydrocarbons and a middle fraction comprising C_5 to C_8 hydrocarbons.

40. The process of claim 39, wherein separating the light fraction from the deasphalted oil/solvent separator comprises condensing the middle fraction.

41. The process of claim 40, wherein the middle fraction is recyclable as the deasphalting solvent for performing the solvent deasphalting.

42. The process of any one of claims 30 to 41, further comprising supplying the solvent fraction from the clarifying column to the deasphalted oil/solvent separator.

43. The process of any one of claims 1 to 42, wherein the asphaltene precipitates from the asphaltenes fraction comprise between about 15 wt% and 20 wt% of residual deasphalted oil.

Date Reçue/Date Received 2021-01-08

44. The process of any one of claims 1 to 42, wherein the asphaltene precipitates from the asphaltenes fraction comprise less than 20 wt% of residual deasphalted oil.

45. The process of any one of claims 1 to 44, further comprising subjecting the asphaltenes fraction to centrifugal separation in an additional centrifugal separation device to further separate solvent therefrom and produce a recovered vaporized solvent stream and dry asphaltene precipitates.

46. The process of claim 45, wherein the additional centrifugal separation device comprises one or more vapour-solid cyclone.

47. The process of claim 45 or 46, wherein the dry asphaltene precipitates comprise less than about 10 wt% of residual deasphalted oil.

48. The process of claim 45 or 46, wherein the dry asphaltene precipitates comprise between about 5 wt% and 10 wt% of residual deasphalted oil.

49. The process of claim 45 or 46, wherein the dry asphaltene precipitates comprise between about 3 wt% and 4 wt% of residual deasphalted oil.

50. The process of claim 45 or 46, wherein the dry asphaltene precipitates comprise less than about 7 wt% of residual deasphalted oil.

51. The process of any one of claims 45 to 50, further comprising condensing the recovered vaporized solvent stream to produce a condensed recovered solvent steam.

52. The process of claim 51, further comprising recycling the condensed recovered solvent steam to the clarifying column as a clarifying solvent.

53. The process of claim 51 or 52, further comprising recycling the condensed recovered solvent steam for use as the deasphalting solvent.

54. The process of any one of claims 1 to 53, wherein the solvent fraction from the clarifying column is recyclable as the deasphalting solvent.

Date Reçue/Date Received 2021-01-08

55. The process of any one of claims 30 to 54, further comprising preventing vapor generation within the centrifugal separation device by providing a backpressure valve downstream of the centrifugal separation device and upstream of the deasphalted oil/solvent separator.

56. The process of any one of claims 45 to 55, further comprising vaporizing solvent present in the asphaltenes fraction from the clarifying column during pipelining from the clarifying column to the additional centrifugal separation device.

57. The process of claim 56, wherein vaporizing solvent present in the asphaltenes fraction from the clarifying column during pipelining from the clarifying column to the additional centrifugal separation device comprising operating a valve provided on a pipeline carrying the asphaltenes fraction to flash the solvent therefrom.

58. The process of any one of claims 1 to 57, wherein the bitumen-containing feedstock comprises bitumen froth obtained from a bitumen froth treatment operation.

59. The process of any one of claims 1 to 57, wherein the bitumen-containing feedstock comprises bitumen obtained from an *in situ* recovery operation.

60. The process of any one of claims 1 to 57, wherein the bitumen-containing feedstock comprises bitumen obtained from an oil sands mining and extraction operation.

61. The process of any one of claims 1 to 57, wherein the bitumen-containing feedstock comprises a heavy bitumen fraction recovered from a distillation column or fractionation column.

62. The process of any one of claims 1 to 57, wherein the bitumen-containing feedstock comprises a thermally-affected heavy fraction produced by a thermal treatment.

63. The process of any one of claims 1 to 57, wherein the bitumen-containing feedstock comprises a thermally-affected asphaltene-rich stream produced by a thermal treatment.

Date Reçue/Date Received 2021-01-08

64. A process for producing a diluent-derived deasphalting solvent, comprising:

supplying a feedstock mixture comprising deasphalted oil and deasphalting solvent to a deasphalted oil/solvent separator;

combining the feedstock mixture with a diluent;

operating the deasphalted oil/solvent separator to produce an overhead stream comprising C_1 to C_8 hydrocarbons, and a bottom stream comprising the deasphalted oil; and

separating the overhead stream to produce a vaporized light fraction comprising C_1 to C_4 hydrocarbons and a condensed middle fraction comprising C_5 to C_8 hydrocarbons, the condensed middle fraction for use as the diluent-derived deasphalting solvent.

65. The process of claim 64, wherein the deasphalted oil/solvent separator is a stripping unit.

66. The process of claim 64 or 65, wherein operating the deasphalted oil/solvent separator comprises injecting a stripping fluid into the deasphalted oil/solvent separator.

67. The process of claim 66, wherein the stripping fluid comprises at least one of natural gas and steam.

68. The process of any one of claims 64 to 67, wherein the diluent comprises at least one of naphtha or condensate.

69. The process of any one of claims 64 to 68, wherein combining the feedstock mixture with the diluent comprises introducing the diluent into the deasphalted oil/solvent separator.

70. The process of any one of claims 64 to 68, wherein combining the feedstock mixture with the diluent comprises mixing the diluent with the feedstock mixture prior to introduction into the deasphalted oil/solvent separator.

Date Reçue/Date Received 2021-01-08

71. The process of any one of claims 64 to 70, further comprising combining the diluent-derived deasphalting solvent with a bitumen-containing feedstock to produce a diluted bitumen stream that includes asphaltene precipitates in suspension in deasphalted oil.

72. The process of claim 71, further comprising subjecting the diluted bitumen stream to centrifugal separation to produce the mixture comprising the deasphalted oil and the deasphalting solvent.

73. The process of claim 71 or 72, wherein the diluent-derived deasphalting solvent is provided in a proportion of about 1.5 to 6 on a mass basis relative to a bitumen content of the bitumen-containing feedstock.

74. The process of claim 71 or 72, wherein the diluent-derived deasphalting solvent is provided in a proportion ranging from about 2 to 5 on a mass basis relative to a bitumen content of the bitumen-containing feedstock.

75. The process of claim 71 or 72, wherein the diluent-derived deasphalting solvent is provided in a proportion ranging from about 2.5 to 4 on a mass basis relative to a bitumen content of the bitumen-containing feedstock.

76. A device for contacting a bitumen-containing feedstock stream with a deasphalting solvent stream to produce a diluted bitumen stream, the device comprising:

a pipeline section comprising:

a feedstock section for flowing the bitumen-containing feedstock stream in a first direction;

a solvent section in fluid communication with the feedstock section for flowing the deasphalting solvent stream in a second direction that is opposite the first direction; and

a mixing zone located at a junction of the feedstock section and the solvent section;

Date Reçue/Date Received 2021-01-08

a diluted bitumen section extending from the junction of the feedstock section and the solvent section and being in fluid communication therewith for receiving a diluted bitumen mixture comprising deasphalted oil and asphaltene precipitates; and

a valve provided on the solvent section for increasing a velocity at which the deasphalting solvent contacts the bitumen-containing feedstock in the mixing zone.

77. The device of claim 76, wherein the feedstock section and the solvent section are provided at an angle of 180° relative to each other.

78. The device of claim 76, wherein the feedstock section and the solvent section are provided at an angle of less than 180° relative to each other.

79. The device of claim 76, wherein the feedstock section and the solvent section are provided at an angle of more than 180° relative to each other.

80. The device of any one of claims 76 to 79, wherein the diluted bitumen section extends from the pipeline section substantially perpendicularly.

81. The device of any one of claims 76 to 79, wherein the diluted bitumen section extends from the pipeline section at an angle ranging from 90° to 45°.

82. The device of any one of claims 76 to 81, wherein the feedstock section has a feedstock section diameter and the solvent section has a solvent section diameter, and the feedstock section diameter is larger than the solvent section diameter.

83. The device of claim 82, wherein a ratio of the solvent section diameter relative to the feedstock section diameter ranges from between 0.3 and 0.7.

84. The device of any one of claims 76 to 83, wherein the feedstock section is configured to flow the bitumen-containing feedstock at a Reynolds number above about 200.

Date Reçue/Date Received 2021-01-08

85. The device of any one of claims 76 to 84, wherein the feedstock section is configured to flow the bitumen-containing feedstock at a Reynolds number ranging from about 2000 and about 5000.

86. The device of any one of claims 76 to 85, wherein the solvent section is configured to flow the deasphalting solvent at a Reynolds number above about 4000.

87. The device of any one of claims 76 to 86, wherein the solvent section is configured to flow the deasphalting solvent at a Reynolds number ranging from about 30 000 to about 35 000.

88. A process for contacting a bitumen-containing feedstock stream and a deasphalting solvent stream to produce a diluted bitumen stream, the process comprising:

flowing the bitumen-containing feedstock stream in a first direction within a feedstock section;

flowing the deasphalting solvent stream in a second direction within a solvent section in fluid communication with the feedstock section, the second direction comprising at least one directional component opposite to the first direction;

increasing a velocity of the deasphalting solvent stream received in the solvent section;

contacting the bitumen-containing feedstock stream and the deasphalting solvent stream in a mixing zone located at a junction of the feedstock section and the solvent section to produce diluted deasphalted oil comprising asphaltene precipitates; and

flowing the diluted deasphalted oil in a diluted bitumen section extending from the junction of the feedstock section and the solvent section and being in fluid communication therewith.

Date Reçue/Date Received 2021-01-08

89. The process of claim 88, wherein the bitumen-containing feedstock stream is flowed within the feedstock section at a velocity ranging from between about 1 cm/s and about 5 cm/s.

90. The process of claim 88 or 89, wherein the deasphalting solvent stream is flowed within the solvent section at a velocity ranging from between about 90 cm/s and about 150 cm/s.

91. The process of any one of claims 88 to 90, wherein the velocity of the deasphalting solvent stream received in the solvent section is increased by operating a valve provided on the solvent section.

92. The process of claim 91, wherein the valve is configured to provide a pressure drop ranging from about 20 psi to about 40 psi.

93. The process of any one of claims 88 to 92, wherein the bitumen-containing feedstock stream is flowed in the first direction within the feedstock section at a Reynolds number above about 200.

94. The process of any one of claims 88 to 93, wherein the bitumen-containing feedstock stream is flowed in the first direction within the feedstock section at a Reynolds number ranging from about 2000 to about 5000.

95. The process of any one of claims 88 to 94, wherein the deasphalting solvent stream is flowed in the second direction within the solvent section at a Reynolds number above about 4000.

96. The process of any one of claims 88 to 95, wherein the deasphalting solvent is flowed in the second direction within the solvent section at a Reynolds number ranging from about 30 000 to about 35 000.

97. The process of any one of claims 88 to 96, further comprising heating the bitumen-containing feedstock stream.

Date Reçue/Date Received 2021-01-08

98. The process of claim 97, wherein the bitumen-containing feedstock stream is heated until the viscosity of the bitumen-containing feedstock stream is reduced below about 1000 cSt.

99. The process of claim 97 or 98, wherein the bitumen-containing feedstock stream is heated until the viscosity of the bitumen-containing feedstock stream is reduced below about 200 cSt.

Date Reçue/Date Received 2021-01-08

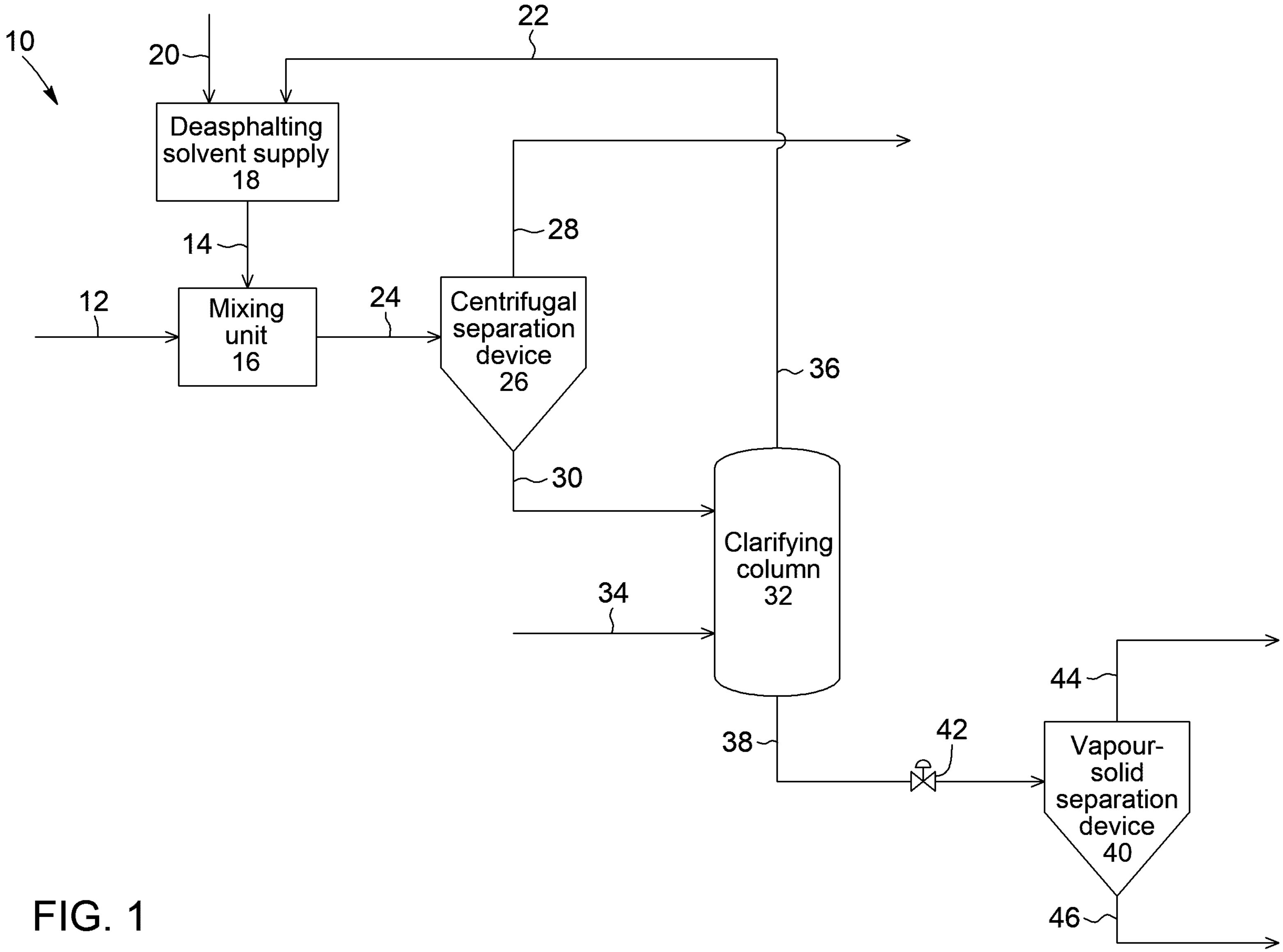


FIG. 1

Date Reçue/Date Received 2021-01-08

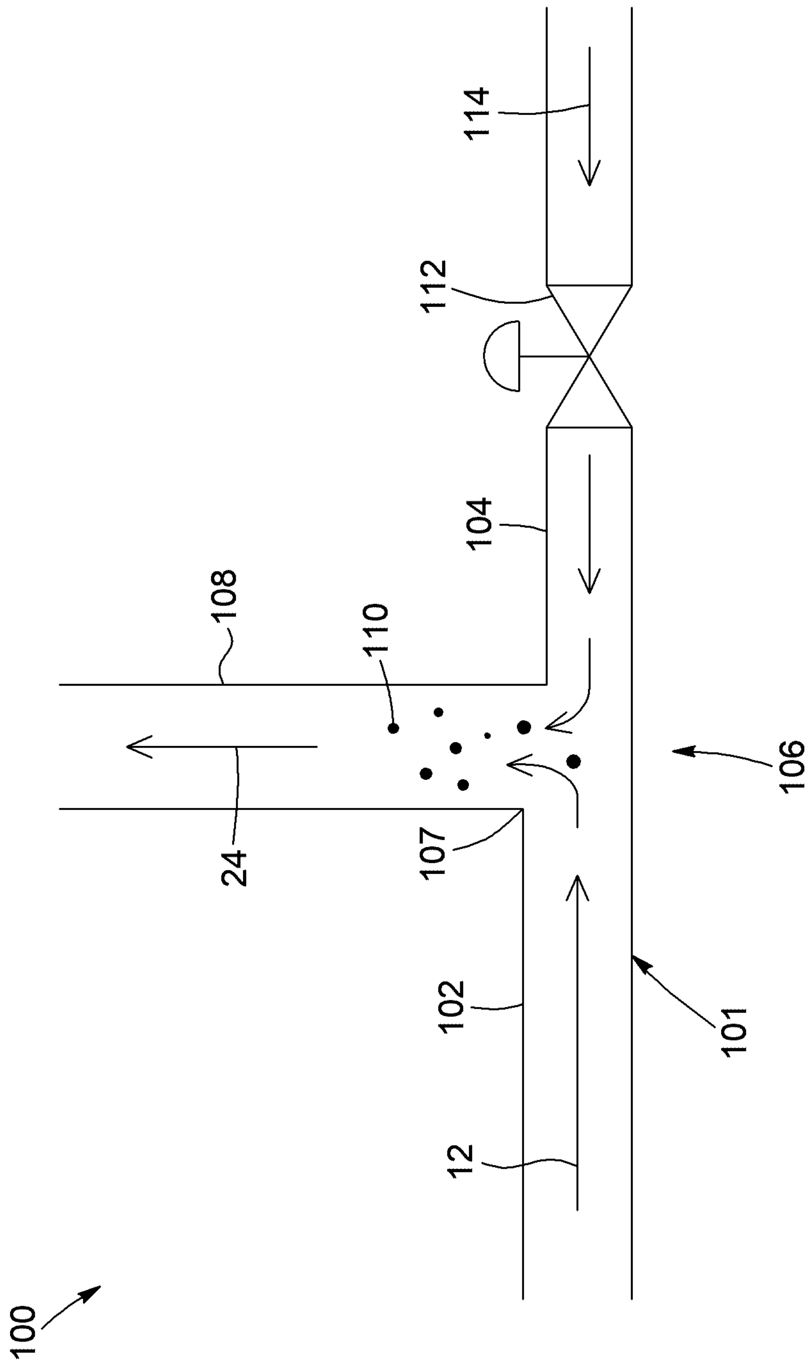


FIG. 2

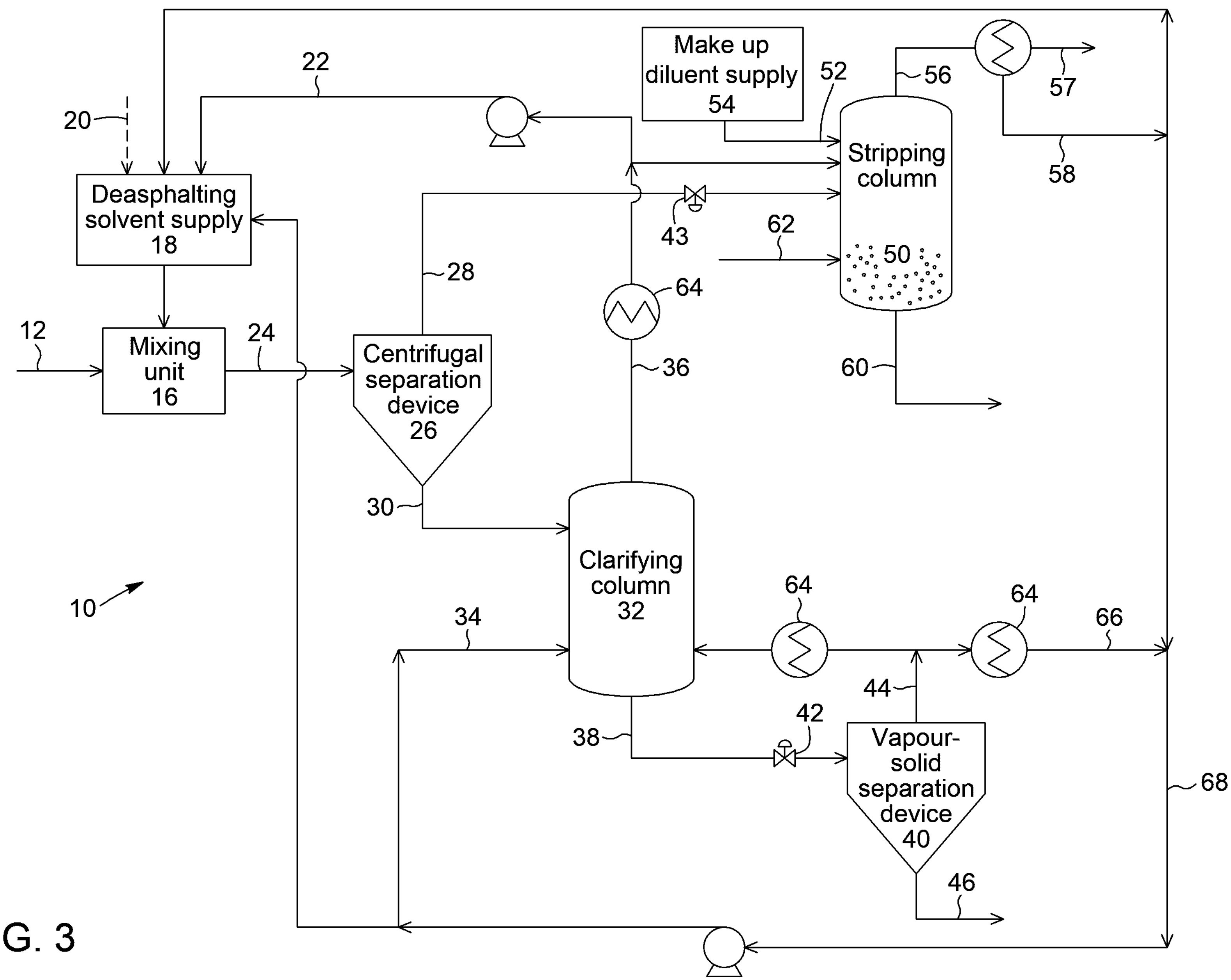
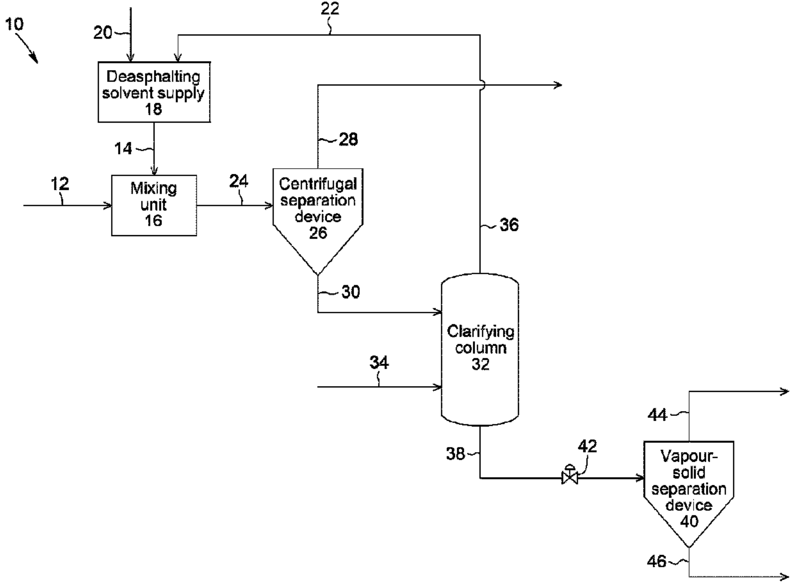


FIG. 3

Date Reçue/Date Received 2021-01-08


10
20
22
Deasphalting solvent supply 18
14
12
Mixing unit 16
24
28
Centrifugal separation device 26
36
30
Clarifying column 32
34
44
38
42
Vapour-solid separation device 40
46