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

Innovation, Science and Economic Development Canada
Canadian Intellectual Property Office

CA 3024329 C 2020/03/31

(11)(21) **3 024 329**

(12) **BREVET CANADIEN**
CANADIAN PATENT

(13) **C**

(22) **Date de dépôt/Filing Date:** 2014/09/12
(41) **Mise à la disp. pub./Open to Public Insp.:** 2016/03/12
(45) **Date de délivrance/Issue Date:** 2020/03/31
(62) **Demande originale/Original Application:** 2 863 571

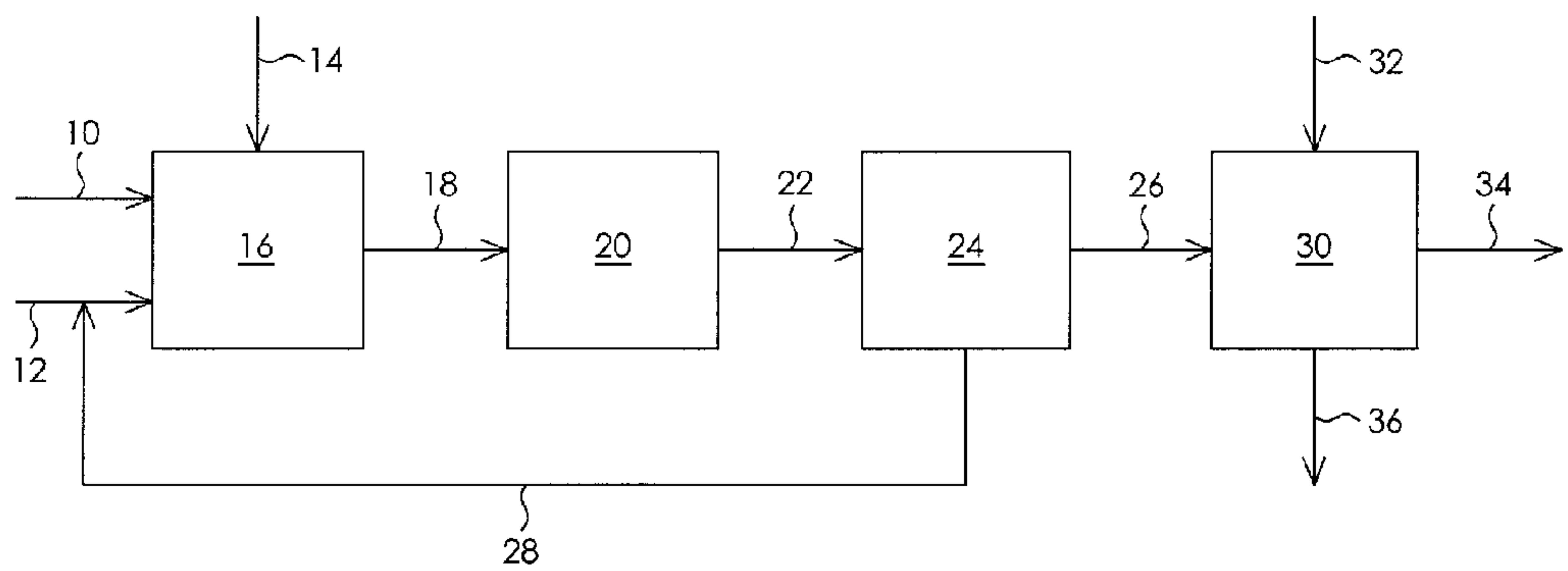
(51) **Cl.Int./Int.Cl.** ***B03B 9/02*** (2006.01), ***B01D 17/035*** (2006.01), ***B03D 1/02*** (2006.01)

(72) **Inventeurs/Inventors:**
OMOTOSO, OLADIPO, CA;
MENDEZ BALBAS, FREDDY E., CA;
GLENDENNING, SEAN PETER SCOTT, CA

(73) **Propriétaire/Owner:**
SUNCOR ENERGY INC., CA

(74) **Agent:** ROBIC

(54) **Titre : EMULSIFICATION ET TRANSPORT DE MOUSSE DE BITUME EN VUE D'EXTRAIRE DES IMPURETES**
(54) **Title: EMULSIFICATION AND TRANSPORTATION OF BITUMEN FROTH FOR REMOVAL OF IMPURITIES**



(57) **Abrégé/Abstract:**
There is provided a process for treating an oil sands aqueous slurry. The oil sands aqueous slurry is subjected to flotation to produce a first aqueous underflow stream comprising solid mineral materials, a middlings stream and a first bitumen froth overflow stream. The middlings stream is subjected to separation in a separation vessel to produce a second aqueous underflow stream and a second bitumen froth overflow stream. An emulsion stabilizer is supplied to the middlings stream or the separation vessel to produce an oil-in-water emulsion having a continuous water phase and a bituminous phase to transfer impurities in the oil-in-water emulsion to the continuous water phase. A first emulsion stabilizer can also be supplied to an oil-in-water emulsion, while a second emulsion stabilizer can be supplied to a middlings stream, the middlings stream then being subjected to separation to produce an aqueous underflow stream and a bitumen froth overflow stream.

ABSTRACT

There is provided a process for treating an oil sands aqueous slurry. The oil sands aqueous slurry is subjected to flotation to produce a first aqueous underflow stream comprising solid mineral materials, a middlings stream and a first bitumen froth overflow stream. The middlings stream is subjected to separation in a separation vessel to produce a second aqueous underflow stream and a second bitumen froth overflow stream. An emulsion stabilizer is supplied to the middlings stream or the separation vessel to produce an oil-in-water emulsion having a continuous water phase and a bituminous phase to transfer impurities in the oil-in-water emulsion to the continuous water phase. A first emulsion stabilizer can also be supplied to an oil-in-water emulsion, while a second emulsion stabilizer can be supplied to a middlings stream, the middlings stream then being subjected to separation to produce an aqueous underflow stream and a bitumen froth overflow stream.

EMULSIFICATION AND TRANSPORTATION OF BITUMEN FROTH FOR REMOVAL OF IMPURITIES

FIELD

[0001] The technical field generally relates to hydrocarbon recovery and, more particularly, to the recovery of bitumen from oil sands.

BACKGROUND

[0002] Extraction of bitumen from oil sands ore generally includes mining the ore, crushing the mined ore, forming an aqueous oil sands slurry including the crushed ore and then subjecting the aqueous oil sands slurry to a bitumen extraction operation in order to recover the bitumen.

[0003] In a bitumen extraction operation, the aqueous oil sands slurry is typically supplied to a primary separation vessel that produces a primary bitumen froth stream, a middlings stream and a tailings stream containing water and coarse minerals solids. The middlings stream and the tailings stream can be supplied to additional separation vessels, which are often flotation cells, in order to recover additional bitumen. The bitumen froth can be further de-aerated to remove air, and combined with a diluent to aid removal of mineral solids and water to produce a bitumen extract for further upgrading operations.

[0004] Some of the bitumen-containing streams produced during the bitumen extraction operation contain relatively high amounts of undesirable materials such as mineral salts (e.g., chloride salts), solid materials and water, which can lower the efficiency of the bitumen extraction and/or lower the quality of the recovered bitumen extract. Some of the bitumen-containing streams also have a relatively high viscosity, which can lead to various difficulties during pipeline transportation.

[0005] Recovering bitumen from oil sands ore still poses a number of challenges.

SUMMARY

[0006] In some implementations, there is provided a process for recovering bitumen from bitumen froth, including: conditioning the bitumen froth to produce an oil-in-water emulsion having a continuous water phase and a bituminous phase, the conditioning including adding an emulsion stabilizer and water to the bitumen froth and dispersing the bituminous phase in the continuous water phase; transporting the oil-in-water emulsion via pipeline for a sufficient residence time so as to produce a transported emulsion wherein impurities from the bituminous phase are transferred to the continuous water phase, the impurities including solid mineral materials; subjecting the transported emulsion to flotation to separate the transported emulsion into an aqueous component including a portion of the emulsion stabilizer and a portion of the solid mineral materials, and a reconstituted bitumen froth; and subjecting the reconstituted bitumen froth to froth treatment to produce extracted bitumen.

[0007] In some implementations, the solid mineral materials include fine solids.

[0008] In some implementations, the flotation includes injecting gas bubbles into the transported emulsion.

[0009] In some implementations, the gas bubbles include air bubbles.

[0010] In some implementations, the bitumen froth is retrieved from a primary bitumen extraction operation.

[0011] In some implementations, the bitumen froth includes a primary bitumen froth, a secondary bitumen froth or a mixture thereof.

[0012] In some implementations, the bitumen froth includes between 40 wt% and 70 wt% bitumen.

[0013] In some implementations, the bitumen froth includes between 20 wt% and 50 wt% water.

[0014] In some implementations, the bitumen froth includes between 5 wt% and 20 wt% solid mineral materials.

[0015] In some implementations, the emulsion stabilizer includes a non-ionic surfactant.

[0016] In some implementations, the non-ionic surfactant includes a non-ionic polymeric surfactant.

[0017] In some implementations, the oil-in-water emulsion has a water-to-bitumen ratio between 3:7 and 1:1.

[0018] In some implementations, the water-to-bitumen ratio is between 2:3 and 3:4.

[0019] In some implementations, the reconstituted bitumen froth has a higher bitumen-to-minerals ratio than the bitumen froth.

[0020] In some implementations, the bitumen froth has a bitumen-to-minerals ratio between 4:1 and 10:1.

[0021] In some implementations, the reconstituted bitumen froth has a bitumen-to-minerals ratio between 10:1 and 25:1.

[0022] In some implementations, the water-to-bitumen ratio of the reconstituted bitumen froth is lower than or equal to the water-to-bitumen ratio of the bitumen froth.

[0023] In some implementations, the froth treatment includes adding a diluent to the reconstituted bitumen froth.

[0024] In some implementations, the step of subjecting the reconstituted bitumen froth to the froth treatment includes: adding the reconstituted froth and a diluent to a froth separation vessel to produce a diluted reconstituted bitumen froth; and separating the diluted reconstituted bitumen froth into a diluted bitumen stream and froth treatment tailings.

[0025] In some implementations, the diluent is added to the reconstituted bitumen froth such that the diluted reconstituted bitumen froth has a diluent-to-bitumen ratio between 0.5 and 0.6.

[0026] In some implementations, the diluent includes a naphthenic type diluent.

[0027] In some implementations, the diluent includes naphtha.

[0028] In some implementations, there is provided a process for recovering bitumen from bitumen froth, including: conditioning the bitumen froth to produce an oil-in-water emulsion having a continuous water phase and a bituminous phase, the conditioning including adding an emulsion stabilizer and water to the bitumen froth and dispersing the bituminous phase in the continuous water phase, wherein impurities in the oil-in-water emulsion are transferred from the bituminous phase to the continuous water phase; separating the oil-in-water emulsion into an aqueous component including a portion of the emulsion stabilizer and a reconstituted bitumen froth including a portion of the bitumen, wherein the separation includes flotation; and subjecting the reconstituted bitumen froth to froth treatment to produce extracted bitumen.

[0029] In some implementations, the transfer of the impurities from the bituminous phase to the continuous water phase is promoted by agitation of the oil-in-water emulsion.

[0030] In some implementations, the agitation to the oil-in-water emulsion includes mixing the oil-in-water emulsion in a conditioning tank.

[0031] In some implementations, the agitation of the oil-in-water emulsion includes transporting the oil-in-water emulsion via pipeline.

[0032]In some implementations, the separating of the oil-in-water emulsion includes supplying the oil-in-water emulsion to a flotation cell and providing gas bubbles into the flotation cell.

[0033]In some implementations, the flotation includes injecting gas bubbles into the oil-in-water emulsion.

[0034]In some implementations, the gas bubbles include air bubbles.

[0035]In some implementations, the bitumen froth is retrieved from a primary bitumen extraction operation.

[0036]In some implementations, the bitumen froth includes a primary bitumen froth, a secondary bitumen froth or a mixture thereof.

[0037]In some implementations, the bitumen froth includes between 40 wt% and 70 wt% bitumen.

[0038]In some implementations, the bitumen froth includes between 20 wt% and 50 wt% water.

[0039]In some implementations, the bitumen froth includes between 5 wt% and 20 wt% solid mineral materials.

[0040]In some implementations, the emulsion stabilizer includes a non-ionic surfactant.

[0041]In some implementations, the non-ionic surfactant includes a non-ionic polymeric surfactant.

[0042]In some implementations, the oil-in-water emulsion has a water-to-bitumen ratio between 3:7 and 1:1.

[0043]In some implementations, the water-to-bitumen ratio is between 2:3 and 3:4.

[0044] In some implementations, the reconstituted bitumen froth has a higher bitumen-to-minerals ratio than the bitumen froth.

[0045] In some implementations, the bitumen froth has a bitumen-to-minerals ratio between 4:1 and 10:1.

[0046] In some implementations, the reconstituted bitumen froth has a bitumen-to-minerals ratio between 10:1 and 25:1.

[0047] In some implementations, the water-to-bitumen ratio of the reconstituted bitumen froth is lower than or equal to the water-to-bitumen ratio of the bitumen froth.

[0048] In some implementations, wherein the froth treatment includes secondary bitumen extraction.

[0049] In some implementations, the step of subjecting the reconstituted bitumen froth to the froth treatment includes: adding the reconstituted froth and a diluent to a froth separation vessel to produce a diluted reconstituted bitumen froth; and separating the diluted reconstituted bitumen froth into a diluted bitumen stream and froth treatment tailings.

[0050] In some implementations, the diluent is added to the reconstituted bitumen froth such that the diluted reconstituted bitumen froth has a diluent-to-bitumen ratio between 0.5 and 0.6.

[0051] In some implementations, the diluent includes a naphthenic type diluent.

[0052] In some implementations, the diluent includes naphtha.

[0053] In some implementations, there is provided a process for treating bitumen froth that includes bitumen, solid mineral materials and water, the process including: conditioning the bitumen froth to produce an oil-in-water emulsion having a continuous water phase and a bituminous phase, wherein: an emulsion stabilizer is present and promotes distribution of the bituminous phase as bitumen droplets within the continuous water phase; and a portion of the solid mineral materials are transferred from the bituminous phase into the continuous water phase; and subjecting the oil-in-water emulsion to flotation to produce an aqueous component including a portion of the emulsion stabilizer and solid mineral materials, and a reconstituted bitumen froth with a reduced concentration of solid mineral materials compared to the bitumen froth.

[0054] In some implementations, the step of conditioning the bitumen froth includes adding the emulsion stabilizer and water to the bitumen froth and agitating to form the oil-in-water emulsion.

[0055] In some implementations, the flotation includes injecting gas bubbles into the oil-in-water emulsion.

[0056] In some implementations, the flotation includes injecting a fluid including dissolved gas into the oil-in-water emulsion at conditions such that the dissolved gas is released to form gas bubbles.

[0057] In some implementations, the flotation includes providing gas bubbles having size, velocity and flow rate based on the size of the bitumen droplets and bitumen concentration in oil-in-water emulsion, so as to provide sufficient bubble flotation to separate substantially all of the bitumen from the oil-in-water emulsion.

[0058] In some implementations, the flotation is performed using air.

[0059] In some implementations, the process further includes recycling at least a portion of the aqueous component in order to re-use the emulsion stabilizer contained therein for conditioning the bitumen froth.

[0060] In some implementations, the process further includes transporting the oil-in-water emulsion from a first location proximate a primary froth separation vessel to a second location proximate a froth treatment operation, prior to the flotation.

[0061] In some implementations, the emulsion stabilizer includes a non-ionic surfactant having low affinity for the solid mineral materials.

[0062] In some implementations, the floatation is performed in a flotation cell, the aqueous component being produced as an underflow stream and the reconstituted bitumen froth being produced as an overflow stream.

[0063] In some implementations, there is provided a process for treating an oil-in-water emulsion that includes a continuous water phase, a bituminous phase, solid mineral materials, and an emulsion stabilizer promoting distribution of the bituminous phase as bitumen droplets within the continuous water phase, the process including: subjecting the oil-in-water emulsion to flotation to produce an aqueous underflow stream including a portion of the emulsion stabilizer and solid mineral materials, and a reconstituted bitumen froth overflow stream.

[0064] In some implementations, the flotation includes injecting gas bubbles into the oil-in-water emulsion.

[0065] In some implementations, the flotation includes injecting a fluid including dissolved gas into the oil-in-water emulsion at conditions such that the dissolved gas is released to form gas bubbles.

[0066] In some implementations, the flotation includes providing gas bubbles having size, velocity and flow rate based on the size of the bitumen droplets and bitumen concentration in oil-in-water emulsion, so as to provide sufficient bubble flotation to separate substantially all of the bitumen from the oil-in-water emulsion.

[0067] In some implementations, the flotation is performed using air.

[0068] In some implementations, there is provided a process for treating an oil-in-water emulsion that comprises a continuous water phase, a bituminous phase, solid mineral materials, and a first emulsion stabilizer promoting distribution of the bituminous phase as bitumen droplets within the continuous water phase. The process comprises subjecting the oil-in-water emulsion to flotation to produce a first aqueous underflow stream comprising a portion of the first emulsion stabilizer and solid mineral materials, a middlings stream and a first bitumen froth overflow stream; supplying a second emulsion stabilizer to the middlings stream; and subjecting the middlings stream to separation to produce a second aqueous underflow stream and a second bitumen froth overflow stream.

[0069] In some implementations, the process further comprises supplying the second bitumen froth overflow stream back to flotation.

[0070] In some implementations, the process further comprises mixing the second bitumen froth overflow stream with the first bitumen froth overflow stream to obtain a mixed bitumen froth overflow stream, and subjecting the mixed bitumen froth overflow stream to froth treatment to produce extracted bitumen.

[0071] In some implementations, the flotation comprises injecting gas bubbles into the oil-in-water emulsion.

[0072] In some implementations, the flotation comprises injecting a fluid comprising dissolved gas into the oil-in-water emulsion at conditions such that the dissolved gas is released to form gas bubbles.

[0073] In some implementations, the flotation comprises providing gas bubbles having size, velocity and flow rate based on the size of the bitumen droplets and bitumen concentration in oil-in-water emulsion, to provide sufficient bubble flotation to separate substantially all of the bitumen from the oil-in-water emulsion.

[0074] In some implementations, the flotation is performed using air.

[0075] In some implementations, at least one of the first emulsion stabilizer and the second emulsion stabilizer comprises a non-ionic surfactant having low affinity for the solids mineral materials.

[0076] In some implementations, at least one of the first emulsion stabilizer and the second emulsion stabilizer comprises a non-ionic surfactant.

[0077] In some implementations, the non-ionic surfactant comprises a non-ionic polymeric surfactant.

[0078] In some implementations, the oil-in-water emulsion has a water-to-bitumen ratio between 3:7 and 1:1.

[0079] In some implementations, the water-to-bitumen ratio is between 2:3 and 3:4.

[0080] In some implementations, there is provided a process for treating an oil-in-water emulsion that comprises a continuous water phase, a bituminous phase, solid mineral materials, and a first emulsion stabilizer promoting distribution of the bituminous phase as bitumen droplets within the continuous water phase. The process comprises subjecting the oil-in-water emulsion to flotation to produce a first aqueous underflow stream comprising a portion of the first emulsion stabilizer and solid mineral materials, a middlings stream and a first bitumen froth overflow stream; and subjecting the middlings stream to separation wherein a second emulsion stabilizer is present to produce a second aqueous underflow stream and a second bitumen froth overflow stream.

[0081] In some implementations, the step of separating the middlings stream is performed in a separation vessel.

[0082] In some implementations, the second emulsion stabilizer is supplied to the separation vessel.

[0083] In some implementations, the process further comprises supplying the second bitumen froth overflow stream back to flotation.

[0084] In some implementations, the process further comprises mixing the second bitumen froth overflow stream with the first bitumen froth overflow stream to obtain a mixed bitumen froth overflow stream, and subjecting the mixed bitumen froth overflow stream to froth treatment to produce extracted bitumen.

[0085] In some implementations, the flotation comprises injecting gas bubbles into the oil-in-water emulsion.

[0086] In some implementations, the flotation comprises injecting a fluid comprising dissolved gas into the oil-in-water emulsion at conditions such that the dissolved gas is released to form gas bubbles.

[0087] In some implementations, the flotation comprises providing gas bubbles having size, velocity and flow rate based on the size of the bitumen droplets and bitumen concentration in oil-in-water emulsion, so as to provide sufficient bubble flotation to separate substantially all of the bitumen from the oil-in-water emulsion.

[0088] In some implementations, the flotation is performed using air.

[0089] In some implementations, at least one of the first emulsion stabilizer and the second emulsion stabilizer comprises a non-ionic surfactant having low affinity for the solids mineral materials.

[0090] In some implementations, at least one of the first emulsion stabilizer and the second emulsion stabilizer comprises a non-ionic surfactant.

[0091] In some implementations, the non-ionic surfactant comprises a non-ionic polymeric surfactant.

[0092] In some implementations, the oil-in-water emulsion has a water-to-bitumen ratio between 3:7 and 1:1.

[0093] In some implementations, the water-to-bitumen ratio is between 2:3 and 3:4.

[0094] In some implementations, there is provided a process for treating an oil sands aqueous slurry that comprises water, bitumen, and solid mineral materials.

The process comprises subjecting the oil sands aqueous slurry to flotation to produce a first aqueous underflow stream comprising solid mineral materials, a middlings stream and a first bitumen froth overflow stream; subjecting the middlings stream to separation in a separation vessel to produce a second aqueous underflow stream and a second bitumen froth overflow stream; and supplying an emulsion stabilizer to the middlings stream or to the separation vessel to produce an oil-in-water emulsion having a continuous water phase and a bituminous phase, comprising dispersing the bituminous phase in the continuous water phase, wherein impurities in the oil-in-water emulsion are transferred to the continuous water phase, the impurities comprising solid mineral materials.

[0095] In some implementations, the process further comprises supplying the second bitumen froth overflow stream back to flotation.

[0096] In some implementations, the process further comprises mixing the second bitumen froth overflow stream with the first bitumen froth overflow stream to obtain a mixed bitumen froth overflow stream, and subjecting the mixed bitumen froth overflow stream to froth treatment to produce extracted bitumen.

[0097] In some implementations, the flotation comprises injecting gas bubbles into the oil-in-water emulsion.

[0098] In some implementations, the flotation comprises injecting a fluid comprising dissolved gas into the oil-in-water emulsion at conditions such that the dissolved gas is released to form gas bubbles.

[0099] In some implementations, the flotation comprises providing gas bubbles having size, velocity and flow rate based on the size of the bitumen droplets and bitumen concentration in oil-in-water emulsion, so as to provide sufficient bubble flotation to separate substantially all of the bitumen from the oil-in-water emulsion.

[0100] In some implementations, the flotation is performed using air.

[0101] In some implementations, the emulsion stabilizer comprises a non-ionic surfactant having low affinity for the solids mineral materials.

[0102] In some implementations, the emulsion stabilizer comprises a non-ionic surfactant.

[0103] In some implementations, the non-ionic surfactant comprises a non-ionic polymeric surfactant.

[0104] In some implementations, the oil-in-water emulsion has a water-to-bitumen ratio between 3:7 and 1:1.

[0105] In some implementations, the water-to-bitumen ratio is between 2:3 and 3:4.

BRIEF DESCRIPTION OF THE DRAWINGS

[0106] Fig 1 is a general process flow diagram of an example process for recovering bitumen from various bitumen-containing streams.

[0107] Fig 2 is a process flow diagram including a conditioning vessel.

[0108] Fig 3 is another process flow diagram including in-line conditioning.

[0109] Fig 4 is a process flow diagram of an example process for recovering bitumen from oil sands, including emulsification and transportation of various bitumen-containing streams.

[0110] Fig 5 is another process flow diagram showing uses of the emulsion stabilizer.

[0111] Fig 6 is a process flow diagram including a flotation unit.

[0112] Fig 7 is a graph showing the formation of reconstituted bitumen froth after flotation of an oil-in-water emulsion obtained from PSV bitumen froth.

DETAILED DESCRIPTION

[0113] Various techniques that are described herein enable recovery of bitumen from bitumen-containing sources or streams by producing an oil-in-water emulsion having a continuous water phase and a bituminous phase, the oil-in-water emulsion being suitable for in-line transportation. In some implementations, the oil-in-water emulsion includes bitumen, water, mineral materials (i.e., impurities) and an emulsion stabilizer. The mineral materials include solubilized minerals and mineral solids, a portion of which can be trapped within bitumen droplets. The oil-in-water emulsion can also have an emulsion stability sufficient to allow the in-line transportation in emulsified form and to facilitate subsequent emulsion breaking after in-line transportation to separate the bitumen from a significant portion of the water, soluble minerals and solid mineral materials.

[0114] Referring to Fig 1, in some implementations, a bitumen-containing stream or source 10 is combined with water 12 and a chemical composition 14 including an emulsion stabilizer in a conditioning stage 16 in order to produce an oil-in-water emulsion 18. The oil-in-water emulsion 18 is subjected to pipeline transport 20 to obtain a "transported emulsion" 22 in which a portion of the mineral materials and/or water (i.e., the impurities) trapped within bitumen droplets are transferred to the continuous water phase. The transported emulsion 22 is then subjected to separation 24 where the emulsion is broken, producing at least a bitumen-rich stream 26 and an aqueous stream 28. The aqueous stream 28, including water and some recovered chemical composition 14, can be recycled back to the conditioning stage 16. The bitumen-rich stream 26 can be a bitumen froth that can be integrated into a bitumen extraction operation 30. The bitumen extraction operation 30 can also receive other bitumen-rich streams 32 and produces bitumen product 34 and extraction tailings 36 which can be further treated or disposed of.

[0115] The bitumen-containing stream or source 10 can include an oil sands slurry including water and crushed oil sands ore, bitumen froth, a middlings stream obtained for example from a primary separation vessel, or other bitumen-containing streams or sources in the bitumen extraction operation. More regarding the bitumen-containing streams or sources will be described further below.

Conditioning and forming oil-in-water emulsion including bitumen

[0116]In some implementations, the bitumen containing source or stream is combined with water and a chemical conditioning composition to form an oil-in-water emulsion that is pipeline transportable. As noted above, the chemical conditioning composition includes an emulsion stabilizer.

[0117]Referring to Fig 2, the bitumen-containing source or stream 10 and the water 12 are separately supplied to a conditioning vessel 38 so as to achieve the desired proportions of bitumen to water. Alternatively, the conditioning vessel 38 can be fed with a single pre-mixed stream including the bitumen-containing stream 10 and the water 12, and make-up water can be added as needed. The conditioning vessel 38 is also supplied with an emulsion stabilizer 40 and optionally with other chemical agents 42 such as alkaline compounds (sodium or potassium hydroxide, for example). It should also be noted that the bitumen-containing stream 10, water 12 and emulsion stabilizer 40 can be combined within the conditioning vessel 38 itself or in-line prior to supplying a combined fluid into the conditioning vessel 38. The conditioning vessel 38 can also have an agitation device 44 for providing sufficient agitation to form the oil-in-water emulsion 18. The agitation can be provided using various mechanisms. The conditioning vessel 38 can also include an emulsion outlet, which can be located in a bottom sidewall of the vessel, for releasing the oil-in-water emulsion 18.

[0118]The oil-in-water emulsion 18 can be released from the conditioning vessel 38 and supplied in-line via pipeline toward the separation unit 24. At least one emulsion pump 46 can be used for pumping the oil-in-water emulsion 18 from the conditioning vessel 38 to the separation unit 24.

[0119]The components of the oil-in-water emulsion 18 can be combined in the conditioning vessel 38 in various ways, depending on the nature of the vessel. The conditioning vessel 38 can be a conditioning tank, as shown in Fig 2.

[0120]Referring to Fig 3, the conditioning stage 16 can alternatively include an in-line configuration having one or more addition lines 48 for adding the various components of the oil-in-water emulsion 18, and an in-line mixer 50 for providing sufficient agitation to form the oil-in-water emulsion 18. The in-line mixer 50 can for example include a static mixer followed by a high shear mixer, but other configurations are possible.

[0121]The oil-in-water emulsion can be formulated in order to provide low viscosity and emulsion stability within desired or pre-determined ranges. For example, the oil-in-water emulsion can have a viscosity below 10,000 cp, below 5,000 cp, or below 2,000 cp. In such scenarios, the continuous water phase of the oil-in-water emulsion is the primary phase in contact with pipe wall during pipeline transportation, which facilitates pipelining of the bitumen in the emulsion.

[0122]Regarding emulsion stability, since the oil-in-water emulsion has appropriate viscosity characteristics for pipelining, the emulsion should be formulated to be stable enough to remain emulsified for the entire pipeline transport length. However, once the emulsion has been transported to the next stage of the process, the bitumen is removed from the emulsion in a separation step that involves emulsion breaking. Emulsion breaking involves destabilizing the oil-in-water emulsion in order to separate a bitumen-rich phase from a solid mineral-enriched aqueous phase. High emulsion stability therefore creates challenges for emulsion breaking. The emulsion stability can therefore be provided so as to be sufficiently high to enable the desired in-line transportation, e.g. over a predetermined length of pipeline at certain flow rate conditions, while remaining low enough to facilitate subsequent emulsion breaking in the separation stage. The emulsion stability can be provided and regulated in various ways. The emulsion stability can be based on the concentration and type of emulsion stabilizer, the bitumen-to-water ratio, and/or the agitation energy imparted to the mixture in order to emulsify the mixture.

[0123] One factor of the oil-in-water emulsion is the bitumen droplet diameter. Decreasing the droplet diameter tends to increase the interfacial surface area of the bitumen, increase the viscosity of the emulsion and increase stability of the emulsion. The droplet diameter can be provided in order to provide a balance between low viscosity as well as appropriate stability for in-line transportation and downstream separation. A range of droplet diameter can be determined for each type of bitumen-containing stream based on laboratory experiments, modeling, simulations and/or empirical trials, for example.

[0124] It is also noted that the oil-in-water emulsion can enable part of the mineral solids, for example the fine solids having a particle size lower than 44 microns, to be carried substantially in the continuous aqueous phase to reduce challenges related to pipelining of fluids containing solid particulates.

[0125] In some implementations, the pipeline can have a length of about 1 kilometre to about 15 kilometers or about 3 kilometers to about 10 kilometers. The pipeline diameters can be about 4 inches to about 12 inches, for example, and the emulsion flow rate can be about 2 m^3/h to about 10 m^3/h for each pipeline, for example. The pipeline can also be shorter than the above example lengths. The pipeline can be configured with the appropriate length to fluidly connect a primary extraction operation with a secondary extraction operation. The flow rate can be modified depending on various factors including the retrieval rate of the bitumen-containing source/stream, flow rate of the bitumen-rich stream to be supplied to an extraction operation, as well as equipment design considerations.

[0126] It should also be noted that the emulsion flow rate through the pipeline can be controlled in accordance with the properties of the emulsion at the upstream and/or downstream end of the pipeline. For example, for a given pipeline length, chemical composition and conditioning, the oil-in-water emulsion can have an insufficient stability at a certain flow rate such that the emulsion would prematurely break down during pipeline transportation. In such a scenario, the flow rate of the emulsion can be controlled to adapt the flow rate to reducing or preventing premature emulsion breakdown.

[0127]The oil-in-water emulsion can include from about 30 wt% to about 70 wt% of water and about 30 wt% to about 70 wt% of bitumen. Narrower ranges can also be used. In addition, since some bitumen-containing sources or streams can contain heterogeneous material, which can vary over time, the water-to-bitumen ratio and other parameters can be modulated in order to achieve certain emulsion properties in operation. For example, variation in the bitumen-to-water ratio can lead to a change the level of agitation and/or concentration of the emulsion stabiliser that is added to form the oil-in-water emulsion.

[0128]The oil-in-water emulsion also includes an emulsion stabilizer that enables the emulsion to be consistent and have an appropriate stability for pipeline transportation and subsequent separation. In some implementations, the emulsion stabilizer includes a non-ionic surfactant which can include a non-ionic polymeric surfactant. In some implementations, the emulsion stabilizer can be selected so as to have transient binding with the bitumen, low affinity for solids that may be in the bitumen-containing stream, and can be at least partially recovered into the aqueous phase according to the particular separation technique that is used (e.g., air floatation).

Separation of bitumen-rich stream

[0129]Referring to Figs 1 and 6, the transported oil-in-water emulsion 22 can be separated into a bitumen-rich stream 26 and an aqueous stream 28 in a separation unit 24. The bitumen-rich stream 26, which includes bitumen, water and other impurities, can be supplied into a bitumen extraction operation 30 for extracting bitumen from the other components of the bitumen-rich stream 26. The aqueous stream 28, which includes water and some of the chemical composition

14 (including the emulsion stabilizer), can be recycled back to be used in the production of the oil-in-water emulsion.

[0130]Referring to Fig 6, the separation of the transported oil-in-water emulsion 22 can include flotation in a flotation unit 52. The transported emulsion 22 can be supplied to the flotation unit 52 along with gas (such as air) 54 that is fed into a lower part of the flotation unit 52. The gas 54 aids the process of separating the bitumen-rich stream 26 as an overflow stream from the aqueous phase 28 that is released as an underflow stream. The transported emulsion 22 can be fed directly into the flotation unit 52 or into a holding tank 56 where the emulsion breaking occurs at least in part and the resulting emulsion-broken stream 58 is supplied to the flotation unit 52. The emulsion breaking can thus occur before or during flotation.

[0131]The formation of an oil-in-water emulsion to obtain a bitumen-rich stream can be used on various bitumen-containing sources or streams in the bitumen extraction operation, as mentioned above. Some implementations in which the emulsion stabilizer can be used in various bitumen-containing sources are described below.

Oil-in-water emulsion of oil sands aqueous slurry

[0132] Now referring to Fig 4, oil sands 62 are recovered in a bitumen extraction operation such as surface mining, for example from open-pit mine, and the mined oil sands ore 64 is crushed in a crushing unit 66 to reduce the size of oil sands ore lumps. The crushed ore 68 is then sent to a rotary breaker 70 to further reduce the size of the oil sands ore lumps and is mixed with water 72 to form an oil sands aqueous slurry 74.

[0133]In some implementations, the aqueous slurry 74 can be combined with an emulsion stabilizer 40 in a conditioning stage 78 in order to form an oil-in-water emulsion 80. The conditioning stage 78 can be performed, as described above, in a conditioning vessel or in-line. The oil-in-water emulsion 80 is then transported via pipeline 82 to obtain a transported emulsion 84 in which a portion of the mineral materials and/or water (i.e., a portion of the impurities) trapped within droplets in the bituminous phase of the emulsion are transferred to the continuous water phase. The transported emulsion 84 is then provided to a primary extraction operation 85 including a primary separation vessel (PSV) 86 for separating bitumen froth 88 as a bitumen-rich overflow stream. Air is injected into the PSV 86 to promote floatation of the separated bitumen to the top of the PSV 86. The bitumen froth 88 can be removed by skimming the surface of the fluid within the PSV 86.

[0134] Referring to Figs 1 and 4, it is understood that when the oil-in-water emulsion includes the oil sands slurry 74 as the bitumen-containing stream 10, the separation stage 24 can include the separation in the primary separation vessel 86 and the bitumen-rich stream 26 corresponds to the bitumen froth 88.

[0135] In known processes of bitumen extraction, the oil sands slurry 74 is directly transported to the primary extraction operation and fed to the PSV 86. In such case, some mineral salts including chloride salts, which are trapped in small water droplets within the bitumen (i.e., in a discontinuous water phase of a water-in-oil emulsion), are carried over to the bitumen froth 88 and to a subsequent froth treatment operation.

[0136] In some implementations, conditioning the oil sands slurry 74 into an oil-in-water emulsion 80 and transporting the oil-in-water emulsion 80 via pipeline enables breaking of the water-in-oil emulsion within the bituminous phase and transferring the small droplets of water including the mineral salts from the bituminous phase to the continuous water phase. In such case, instead of being carried over to the bitumen froth 88, using an oil-in-water emulsion can enable part of the mineral salts to report to primary tailings 90, which are recovered as a bottoms tailings stream from the PSV 86. The primary tailings 90 can be further treated or disposed of (for example in a tailings pond 91).

Addition of emulsion stabilizer to middlings

[0137]Referring to Fig 4, the primary extraction operation 85 includes the PSV 86 which separates the oil sands slurry 74 or the transported emulsion 84 into bitumen froth 88 and primary tailings 90. Optionally, a middlings stream 92 is also recovered from a middle section of the PSV 86. The middlings stream 92 can be fed into a secondary separation vessel 94 (SSV) to be separated into secondary bitumen froth 96 (recovered as an overflow stream from the secondary separation vessel 94) and secondary tailings 98 (recovered as an underflow stream from the secondary separation vessel 94). The secondary bitumen froth 96 can be supplied back to the PSV 86 or can be mixed with the primary bitumen froth for further separations and/or treatments. The secondary tailings 98 can be further treated, or disposed of (for example in tailings pond 91).

[0138]In some implementations, an emulsion stabilizer 40 is added to the middlings stream 92 prior to the separation in the secondary separation vessel 94. Alternatively, the emulsion stabilizer 40 can be directly added to the secondary separation vessel 94. The addition of the emulsion stabilizer 40, which is chosen to have low affinity for mineral solids, facilitates viscosity reduction as well as enabling the surfaces of the bitumen droplets to have reduced affinity for the mineral solids contained in the middlings stream 92. The emulsion stabilizer 40 can thus reduce the entrainment or carry-over of mineral solids into the bitumen-rich secondary overflow stream (i.e., the secondary bitumen froth) 96. The middlings stream 92 already being an oil-in-water emulsion, a conditioning stage is typically not required in this case.

[0139]Referring to Figs 1 and 4, it is understood that when the oil-in-water emulsion includes the middlings stream 92 as the bitumen-containing source 10, the separation stage 24 corresponds to the separation in the secondary separation vessel 94 and the bitumen-rich stream 26 corresponds to the secondary bitumen froth 96.

Oil-in-water emulsion of bitumen froth

[0140] Bitumen froth 88 can include between 40 wt% and 70 wt% bitumen, between 20 wt% and 50 wt% water, and between 5 wt% and 10 wt% solid mineral materials, for example. The solid mineral materials in the bitumen froth 22 include hydrophilic mineral materials and heavy minerals. The solid mineral materials and the water are typically separated from the bitumen froth in a froth treatment operation (or secondary bitumen extraction operation), in order to obtain a bitumen-enriched product. However, the bitumen froth includes micrometer-sized mineral particles (mainly clays) and water-in-oil emulsion droplets that are challenging to remove from the bitumen froth with known froth treatment processes.

[0141]In some implementations, the bitumen froth 88 is retrieved from a primary bitumen extraction operation 85 including a PSV 86 and a SSV 94, as described above. The bitumen froth 88 can include the primary bitumen froth recovered as an overflow from the PSV 86, the secondary bitumen froth 96 recovered as an overflow from the SSV 94 or a mixture thereof.

[0142]Referring to Fig 4, in some implementations, the bitumen froth 88 is contacted with water 100 and an emulsion stabilizer 40 in a conditioning stage 102, in order to form an oil-in-water emulsion 104 that is pipeline-transportable. The conditioning stage 102 can be performed, as described above, in a conditioning vessel or in-line. The oil-in-water emulsion 104 is then transported via pipeline 106 to obtain a transported emulsion 108 in which a portion of the mineral materials and/or water (i.e., a portion of the impurities) trapped within droplets in the bituminous phase of the emulsion are transferred to the continuous water phase. The transported emulsion 108 is then provided to a separation unit 110, which can include a flotation unit, for separating the transported emulsion 108 into reconstituted bitumen froth 112 and an aqueous component 114 including part of the emulsion stabilizer 40 and part of the mineral materials. The reconstituted bitumen froth 112 can be recovered as an overflow from the flotation unit 110 and the aqueous component 114 can be recovered as an underflow from the flotation unit 110. The aqueous component 114 can be recycled, for example to be used as water 100 and emulsion stabilizer 40 in the conditioning stage 102, or can be disposed of in a tailings pond 91.

[0143] In some implementations, the emulsion stabilizer used in the oil-in-water emulsion derived from bitumen froth includes Transflux™ available from Oilflow Solutions Inc., Calgary, Canada. Transflux™, which has been used as a transport solution for heavy oil and bitumen.

[0144] In some implementations, the oil-in-water emulsion 104 has a water-to-bitumen ratio between 3:7 and 1:1, or between 2:3 and 3:4. In some implementations, the reconstituted bitumen froth 112 has a higher bitumen-to-minerals ratio than the bitumen froth 88. For example, the bitumen froth 88 can have a bitumen-to-minerals ratio between 4:1 and 10:1, and the reconstituted bitumen froth 112 can have a bitumen-to-minerals ratio between 10:1 and 25:1. In some implementations, the water-to-bitumen ratio of the reconstituted bitumen froth 112 is lower than or equal to the water-to-bitumen ratio of the bitumen froth 88. It is understood that the ratios referred to are by weight of the various constituents.

[0145] The reconstituted bitumen froth 112 is subjected to froth treatment 116 to extract bitumen therefrom. The froth treatment 116 can include supplying the reconstituted froth 112 and a diluent 118 to a froth separation vessel to produce a diluted reconstituted bitumen froth, and separating the diluted reconstituted bitumen froth into a diluted bitumen product 120 and froth treatment tailings 122. The froth treatment tailings 122 can be further treated or disposed of, for example in a tailings pond 91.

[0146] In some implementations, the diluent 118 is added to the reconstituted bitumen froth such that the diluted reconstituted bitumen froth has a diluent-to-bitumen ratio between 0.5 and 0.6. In some implementations, the diluted bitumen product 120 is sent to a diluent recovery unit 124 to obtain a bitumen product 126 and recovered diluent 128. The recovered diluent 128 can be recycled as at least part of the diluent 118 in the secondary bitumen extraction 116. It is understood that the diluent 118 can be either a naphthenic type diluent or a paraffinic type diluent. The naphthenic type diluent can for example include toluene, naphtha or other light aromatic compounds. The paraffinic type diluent can for example include C_4 to C_8 aliphatic compounds and/or natural gas condensate.

[0147] In some implementations, agitation is provided to the oil-in-water emulsion 104 so as to promote transfer of the impurities from the bituminous phase to the continuous water phase. The agitation can be in the form of transportation via pipeline (as explained above) or mechanical mixing of the oil-in-water emulsion 104 (for example in a holding tank) prior to transport.

[0148] Referring to Figs 1 and 4, it is understood that when the oil-in-water emulsion includes the bitumen froth 88 as the bitumen-containing source 10, the separation stage 24 corresponds to the separation in the separation unit 110 and the bitumen-rich stream 26 corresponds to the reconstituted bitumen froth 112.

Supplying of the emulsion stabilizer

[0149] Referring now to Fig 5, the emulsion stabilizer 40 can be used in several applications in the bitumen extraction operation. For example, an emulsion stabilizer source 130 can supply emulsion stabilizer 40 to at least one of conditioning stage 78 (for conditioning of the oil-in-water emulsion of aqueous slurry 74), conditioning stage 102 (for conditioning of the oil-in-water emulsion of the bitumen froth 88), middlings stream 92 (prior to the separation in the SSV 94, or directly into the SSV 94) and/or other suitable bitumen-containing streams in the bitumen extraction operation.

[0150] An example of another suitable bitumen-containing stream in the bitumen extraction operation is tailings bitumen 132, which can be recovered from a tailings pond 91. In some implementations, the tailings bitumen is degraded bitumen which can be emulsified, regenerated and transported. In the case of degraded tailings bitumen, other chemical agents 42 (such as caustic) can be added in conjunction with the emulsion stabilizer 40 in a conditioning stage 134 to form an oil-in-water emulsion and regenerate the degraded tailings bitumen before and/or during transportation. The conditioning stage 134 is similar to the conditioning stages described above and can be performed in a conditioning vessel or in-line.

Additional implementations for hydrocarbon-containing streams

[0151]The emulsion stabilizer can be used in additional applications in various hydrocarbon extraction operations, for example to reduce the chloride content in the extracted hydrocarbons. The hydrocarbons can include bitumen as described above, or can include other types of hydrocarbons such as heavy oil which are not necessarily extracted from oil sands ore and which can thus have lower solids content.

[0152]In some implementations, there is provided a process for recovering hydrocarbons including conditioning a hydrocarbon-containing stream that includes impurities to produce an oil-in-water emulsion having a continuous water phase and a hydrocarbon phase, the conditioning including adding an emulsion stabilizer and water to the hydrocarbon-containing stream and dispersing the hydrocarbon phase in the continuous water phase.

[0153]The process also includes providing agitation to the oil-in-water emulsion so as to promote transfer of impurities (e.g., chlorides) from the hydrocarbon phase into the continuous water phase. Providing agitation to the oil-in-water emulsion can include transporting the oil-in-water emulsion via pipeline to a separation unit.

[0154]The process also includes separating the oil-in-water emulsion in the separation unit into an aqueous component including a portion of the emulsion stabilizer and a portion of the impurities, and a hydrocarbon-rich component. In some implementations, the separation unit is a flotation unit. The emulsion stabilizer can be selected in accordance with the composition of the hydrocarbon-containing stream and the nature of the hydrocarbons, such that the emulsion stabilizer has transient binding with the hydrocarbons, has low affinity for any solids that may be in the hydrocarbon-containing stream, and can be recovered into the aqueous phase according to the particular separation technique that is used (e.g., air floatation).

[0155] In some implementations, additional agents can be added to the bitumen-containing stream or the hydrocarbon-containing stream, to enable desired effects or properties. For instance, caustic or another base can be added to bitumen-containing streams that include degraded bitumen in order to enable regeneration of the bitumen.

Flotation implementations

[0156] Various types of flotation can be performed in order to promote separation of the oil-in-water emulsion. For example, the oil-in-water emulsion can be supplied to a flotation cell and flotation can include injecting gas bubbles directly into a lower part of the flotation cell via various nozzle or sparge configurations. The flotation can also include injecting a fluid that includes dissolved gas under pressure such that under the flotation conditions the dissolved gas is released to form gas bubbles. The flotation can also be performed using cavitation. Various mixing devices can also be used within the flotation cell (e.g., impellers, pump-around, etc.). It should be noted that other flotation methods can also be used for separating the oil-in-water emulsion. In some implementations, the gas bubbles can include microbubbles.

[0157] In addition, the flotation can include supplying gas bubbles having certain characteristics (e.g. bubble size, flow rate, and/or velocity) according to the viscosity and bitumen droplet size of the oil-in-water emulsion in order to enhance flotation performance. For example, when the oil-in-water emulsion contains a higher proportion of bitumen to be recovered, as may be the case when treating bitumen froth, a higher velocity and flow rate of gas bubbles can be used. In some implementations, the size of the air bubbles can be adjusted to match the bitumen droplet size. For example, for smaller bitumen droplet sizes, smaller air bubbles can be used. The gas bubble characteristics can be determined based on calculations, simulations and/or laboratory tests. In addition, in some implementations, the viscosity and/or bitumen droplet size of the oil-in-water emulsion can be determined or estimated on an ongoing basis, and characteristics of the gas bubbles in the flotation step can be varied accordingly.

EXAMPLE

[0158] Experiments were performed to illustrate the conditioning of bitumen froth to obtain an oil-in-water emulsion and subsequent separation of the oil-in-water emulsion to obtain a reconstituted bitumen froth.

[0159] The oil-in-water emulsion was created from a bitumen froth from a primary separation vessel (PSV froth). Transflux™ (on a per bitumen basis) was added to the bitumen froth during the conditioning stage and the mixture was agitated to obtain the emulsion.

[0160] Flotation tests were conducted in a 1.5 L BEU. The BEU was filled with 1.4 kg of the emulsion. To ensure a homogeneous bitumen droplet size, the emulsion was mixed at 1200 rpm for 5 minutes. After 5 minutes, the impeller speed was reduced to 400 rpm and air was introduced at 7 mL/s. Mixing was stopped at regular intervals (30 mins or 1 hour) to allow collection of the accumulated froth. The reconstituted bitumen froth was collected during 13 hours and analyzed to determine the bitumen, water and mineral contents. The results are summarized in Fig 8 and table 2 below.

[0161] Table 1: composition of the PSV froth, oil-in-water emulsion and reconstituted bitumen froth.

Stream	Average Bitumen/mineral	Average Bitumen/water	Average solids % in emulsified water	Bitumen:Mineral: Water
PSV Froth	7.0	1.5	17.6	55:8:37
Emulsion	7.0	0.7	8.6	38:5:57
Reconstituted froth	18.5	1.6	9.0	60:3:37

[0162]According to the tests, 94% of the bitumen was recovered in the reconstituted bitumen froth. The bitumen to mineral ratio in the reconstituted froth was increased more than two-fold and the bitumen to water ratio in the reconstituted froth was substantially similar compared to the PSV froth.

[0163]The solids content of the emulsified water was similar in the emulsion and the reconstituted bitumen froth. Therefore, the minerals remained in the emulsified water phase and showed little affinity for adsorption on bitumen droplets. The emulsified water in the reconstituted froth was carried over to the froth layer during flotation through the hydrodynamics in the flotation cell rather than bitumen droplet affinity for water droplets.

CLAIMS

1. A process for treating an oil-in-water emulsion that comprises a continuous water phase, a bituminous phase, solid mineral materials, and a first emulsion stabilizer promoting distribution of the bituminous phase as bitumen droplets within the continuous water phase, the process comprising:

   subjecting the oil-in-water emulsion to flotation to produce a first aqueous underflow stream comprising a portion of the first emulsion stabilizer and solid mineral materials, a middlings stream and a first bitumen froth overflow stream;

   supplying a second emulsion stabilizer to the middlings stream; and

   subjecting the middlings stream to separation to produce a second aqueous underflow stream and a second bitumen froth overflow stream.

2. The process of claim 1, further comprising supplying the second bitumen froth overflow stream back to flotation.

3. The process of claim 1, further comprising mixing the second bitumen froth overflow stream with the first bitumen froth overflow stream to obtain a mixed bitumen froth overflow stream, and subjecting the mixed bitumen froth overflow stream to froth treatment to produce extracted bitumen.

4. The process of any one of claims 1 to 3, wherein the flotation comprises injecting gas bubbles into the oil-in-water emulsion.

5. The process of any one of claims 1 to 3, wherein the flotation comprises injecting a fluid comprising dissolved gas into the oil-in-water emulsion at conditions such that the dissolved gas is released to form gas bubbles.

6. The process of any one of claims 1 to 3, wherein the flotation comprises providing gas bubbles having size, velocity and flow rate based on the size of the bitumen droplets and bitumen concentration in oil-in-water emulsion, to provide sufficient bubble flotation to separate substantially all of the bitumen from the oil-in-water emulsion.

7. The process of any one of claims 1 to 3, wherein the flotation is performed using air.

8. The process of any one of claims 1 to 7, wherein at least one of the first emulsion stabilizer and the second emulsion stabilizer comprises a non-ionic surfactant having low affinity for the solids mineral materials.

9. The process of any one of claims 1 to 7, wherein at least one of the first emulsion stabilizer and the second emulsion stabilizer comprises a non-ionic surfactant.

10. The process of claim 9, wherein the non-ionic surfactant comprises a non-ionic polymeric surfactant.

11. The process of any one of claims 1 to 10, wherein the oil-in-water emulsion has a water-to-bitumen ratio between 3:7 and 1:1.

12. The process of claim 11, wherein the water-to-bitumen ratio is between 2:3 and 3:4.

13. A process for treating an oil-in-water emulsion that comprises a continuous water phase, a bituminous phase, solid mineral materials, and a first emulsion stabilizer promoting distribution of the bituminous phase as bitumen droplets within the continuous water phase, the process comprising:

    subjecting the oil-in-water emulsion to flotation to produce a first aqueous underflow stream comprising a portion of the first emulsion stabilizer and solid mineral materials, a middlings stream and a first bitumen froth overflow stream; and subjecting the middlings stream to separation wherein a second emulsion stabilizer is present to produce a second aqueous underflow stream and a second bitumen froth overflow stream.

14. The process of claim 13, wherein the step of separating the middlings stream is performed in a separation vessel.

15. The process of claim 14, wherein the second emulsion stabilizer is supplied to the separation vessel.

16. The process of any one of claims 13 to 15, further comprising supplying the second bitumen froth overflow stream back to flotation.

17. The process of any one of claims 13 to 15, further comprising mixing the second bitumen froth overflow stream with the first bitumen froth overflow stream to obtain a mixed bitumen froth overflow stream, and subjecting the mixed bitumen froth overflow stream to froth treatment to produce extracted bitumen.

18. The process of any one of claims 13 to 17, wherein the flotation comprises injecting gas bubbles into the oil-in-water emulsion.

19. The process of any one of claims 13 to 17, wherein the flotation comprises injecting a fluid comprising dissolved gas into the oil-in-water emulsion at conditions such that the dissolved gas is released to form gas bubbles.

20. The process of any one of claims 13 to 17, wherein the flotation comprises providing gas bubbles having size, velocity and flow rate based on the size of the bitumen droplets and bitumen concentration in oil-in-water emulsion, so as to provide sufficient bubble flotation to separate substantially all of the bitumen from the oil-in-water emulsion.

21. The process of any one of claims 13 to 17, wherein the flotation is performed using air.

22. The process of any one of claims 13 to 21, wherein at least one of the first emulsion stabilizer and the second emulsion stabilizer comprises a non-ionic surfactant having low affinity for the solids mineral materials.

23. The process of any one of claims 13 to 21, wherein at least one of the first emulsion stabilizer and the second emulsion stabilizer comprises a non-ionic surfactant.

24. The process of claim 23, wherein the non-ionic surfactant comprises a non-ionic polymeric surfactant.

25. The process of any one of claims 13 to 24, wherein the oil-in-water emulsion has a water-to-bitumen ratio between 3:7 and 1:1.

26. The process of claim 25, wherein the water-to-bitumen ratio is between 2:3 and 3:4.

27. A process for treating an oil sands aqueous slurry that comprises water, bitumen, and solid mineral materials, the process comprising:

subjecting the oil sands aqueous slurry to flotation to produce a first aqueous underflow stream comprising solid mineral materials, a middlings stream and a first bitumen froth overflow stream;

subjecting the middlings stream to separation in a separation vessel to produce a second aqueous underflow stream and a second bitumen froth overflow stream; and

supplying an emulsion stabilizer to the middlings stream or to the separation vessel to produce an oil-in-water emulsion having a continuous water phase and a bituminous phase, comprising dispersing the bituminous phase in the continuous water phase, wherein impurities in the oil-in-water emulsion are transferred to the continuous water phase, the impurities comprising solid mineral materials.

28. The process of claim 27, further comprising supplying the second bitumen froth overflow stream back to flotation.

29. The process of claim 27, further comprising mixing the second bitumen froth overflow stream with the first bitumen froth overflow stream to obtain a mixed bitumen froth overflow stream, and subjecting the mixed bitumen froth overflow stream to froth treatment to produce extracted bitumen.

30. The process of any one of claims 27 to 29, wherein the flotation comprises injecting gas bubbles into the oil-in-water emulsion.

31. The process of any one of claims 27 to 29, wherein the flotation comprises injecting a fluid comprising dissolved gas into the oil-in-water emulsion at conditions such that the dissolved gas is released to form gas bubbles.

32. The process of any one of claims 27 to 29, wherein the flotation comprises providing gas bubbles having size, velocity and flow rate based on the size of the bitumen droplets and bitumen concentration in oil-in-water emulsion, so as to provide sufficient bubble flotation to separate substantially all of the bitumen from the oil-in-water emulsion.

33. The process of any one of claims 27 to 29, wherein the flotation is performed using air.

34. The process of any one of claims 27 to 33, wherein the emulsion stabilizer comprises a non-ionic surfactant having low affinity for the solids mineral materials.

35. The process of any one of claims 27 to 33, wherein the emulsion stabilizer comprises a non-ionic surfactant.

36. The process of claim 35, wherein the non-ionic surfactant comprises a non-ionic polymeric surfactant.

37. The process of any one of claims 27 to 36, wherein the oil-in-water emulsion has a water-to-bitumen ratio between 3:7 and 1:1.

38. The process of claim 37, wherein the water-to-bitumen ratio is between 2:3 and 3:4.

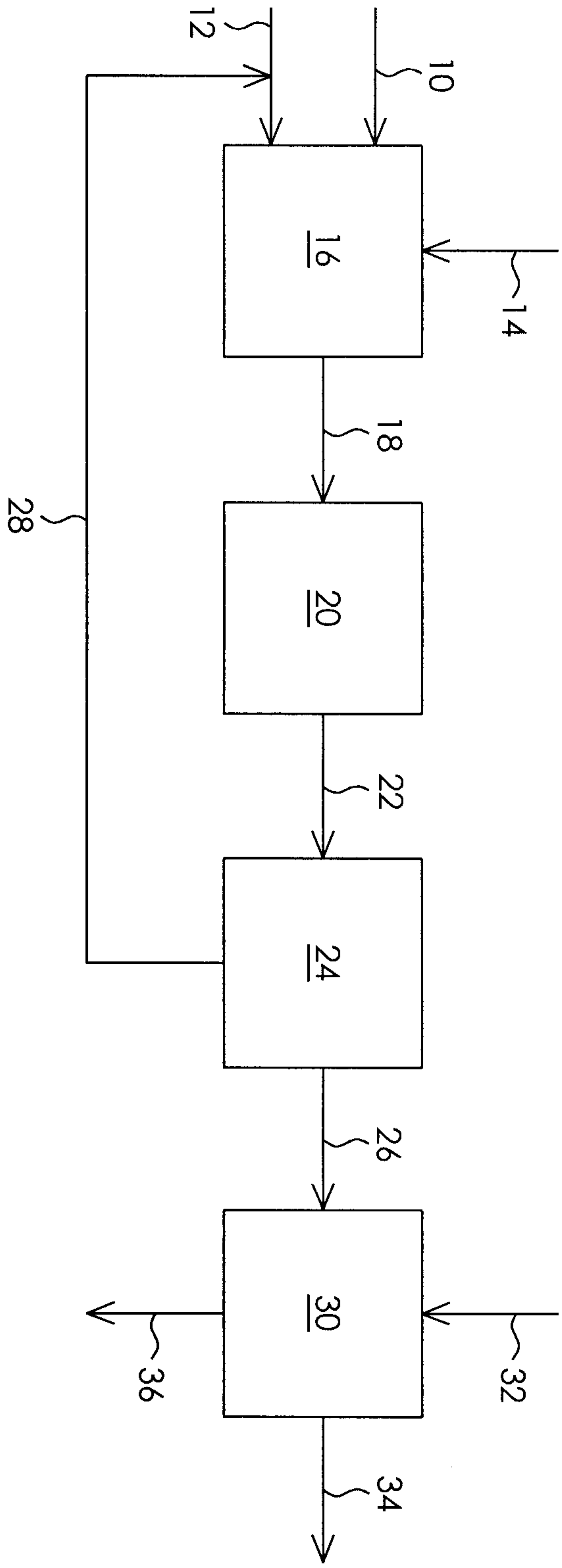


FIG. 1

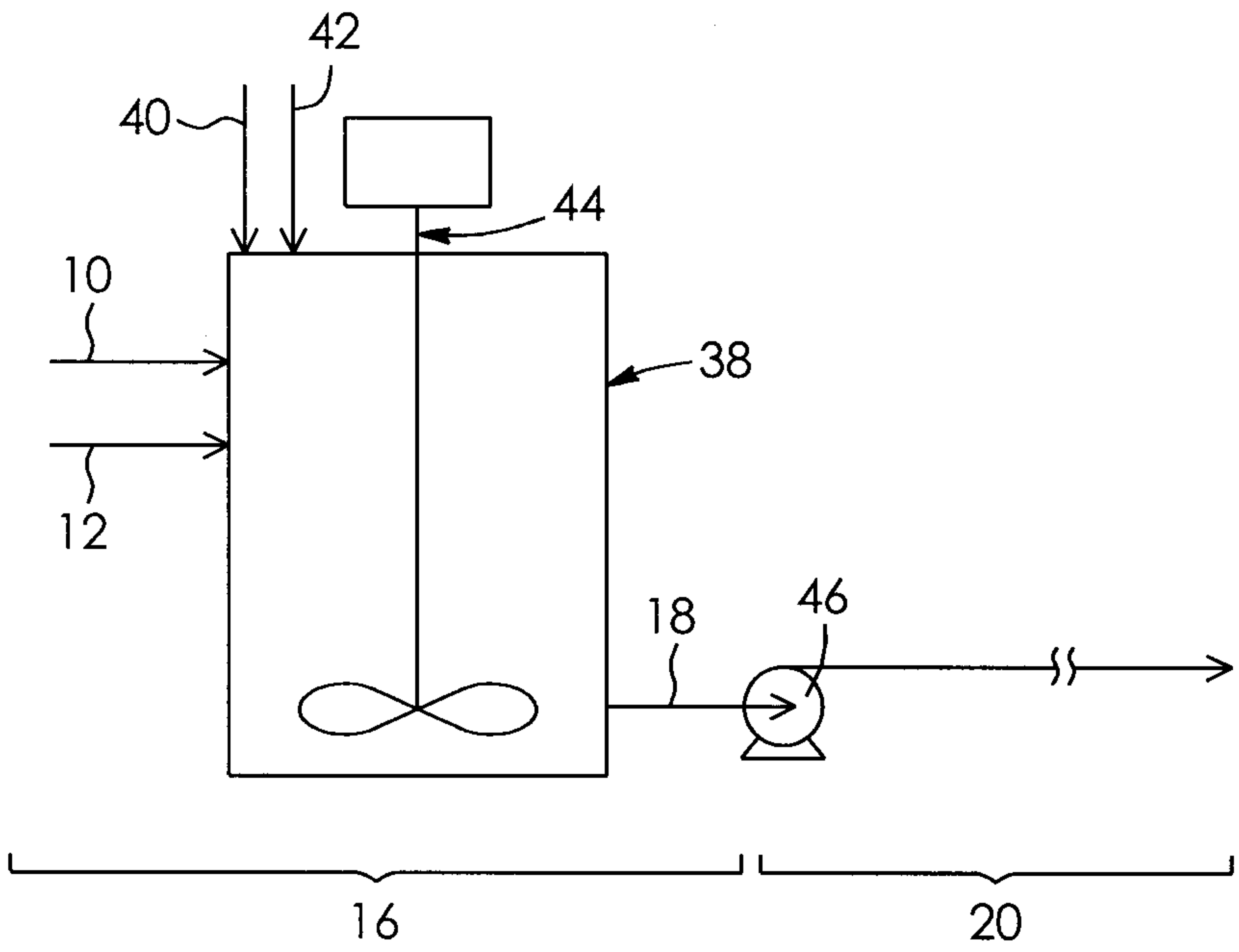


FIG. 2

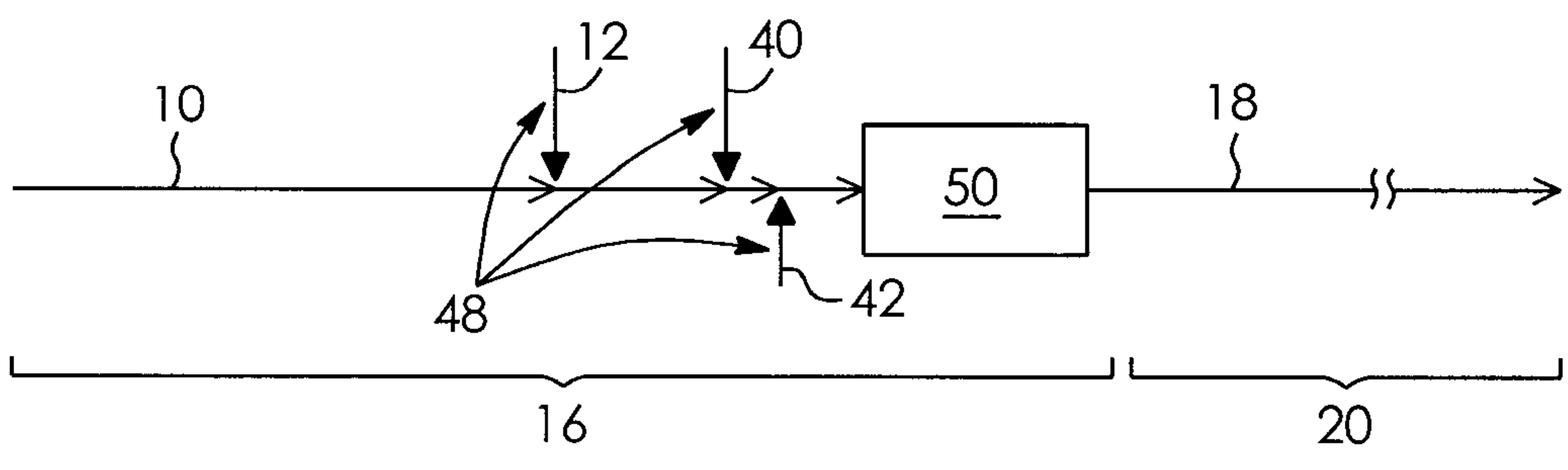


FIG. 3

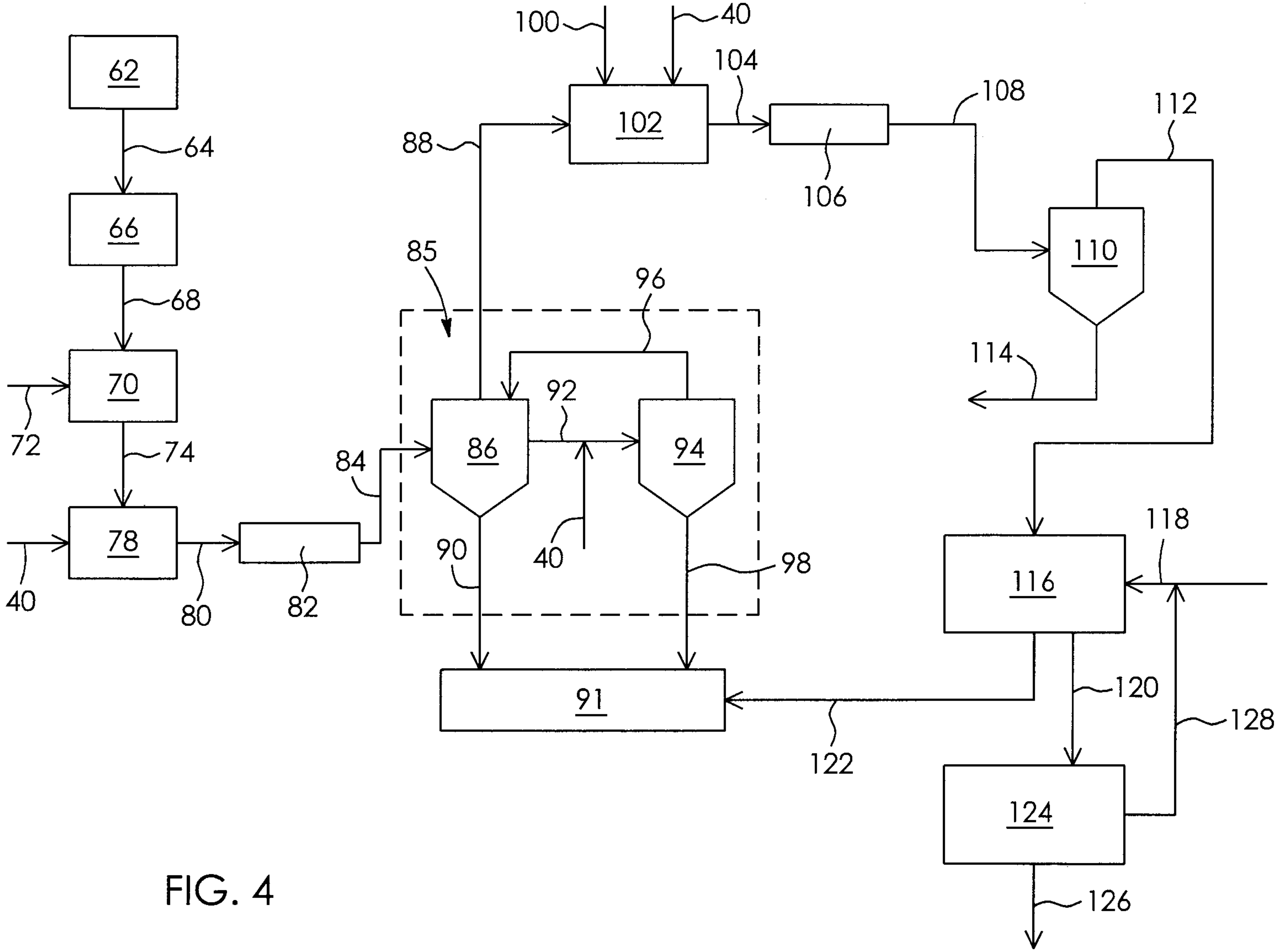

62
64
66
68
70
72
74
78
40
80
82
84
85
86
88
90
91
92
40
94
96
98
100
40
102
104
106
108
110
112
114
116
118
120
122
124
126
128

FIG. 4

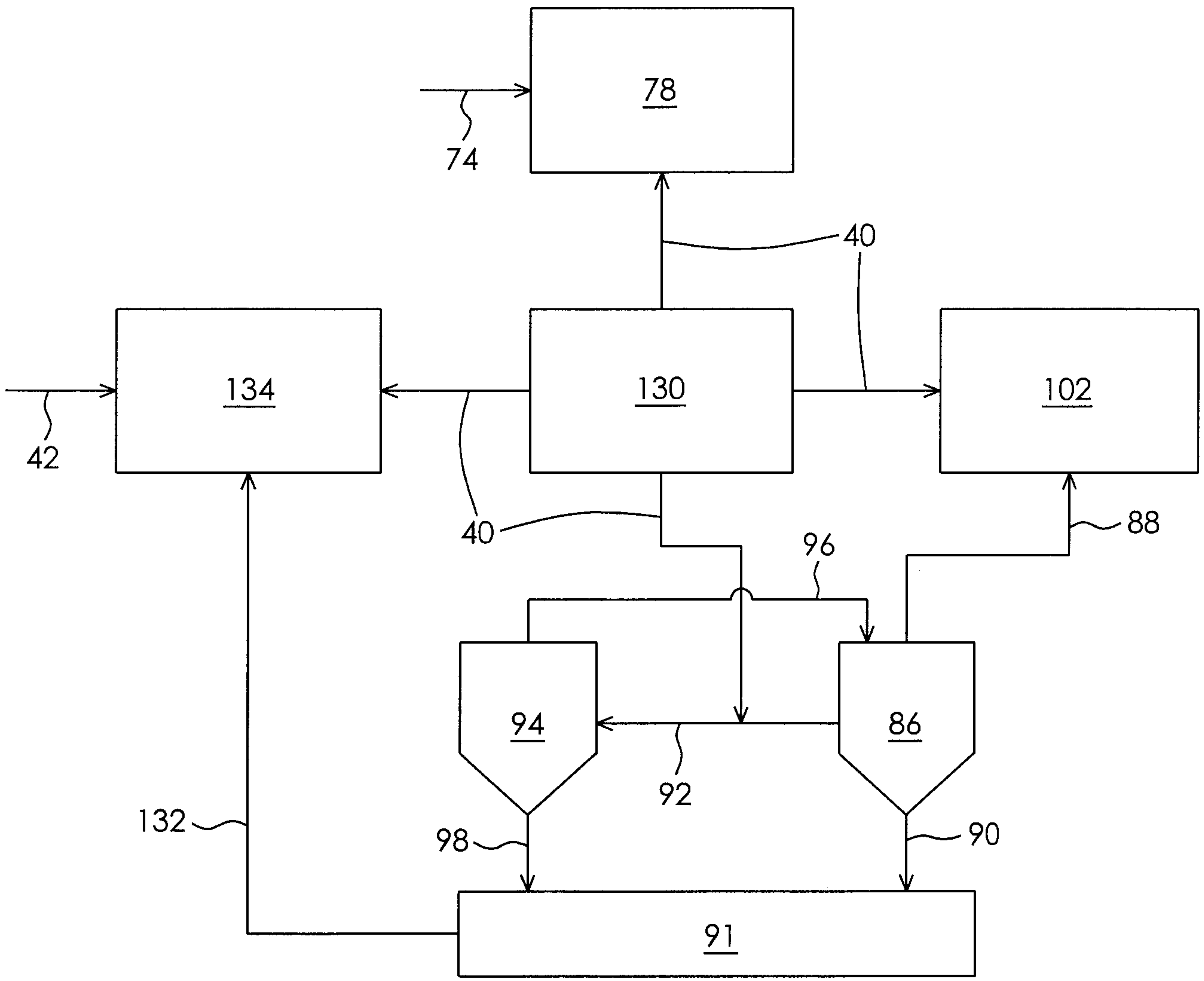


FIG. 5

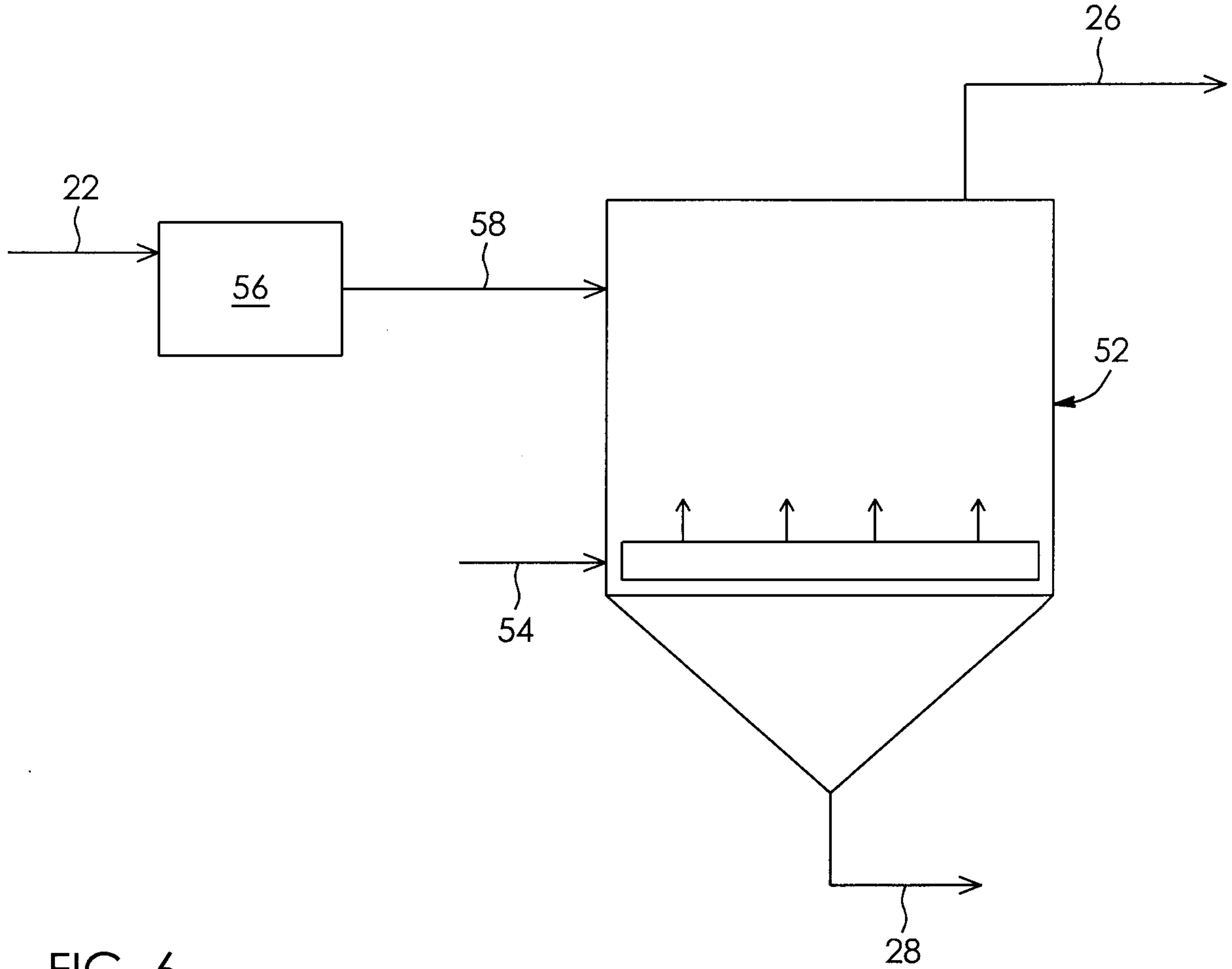
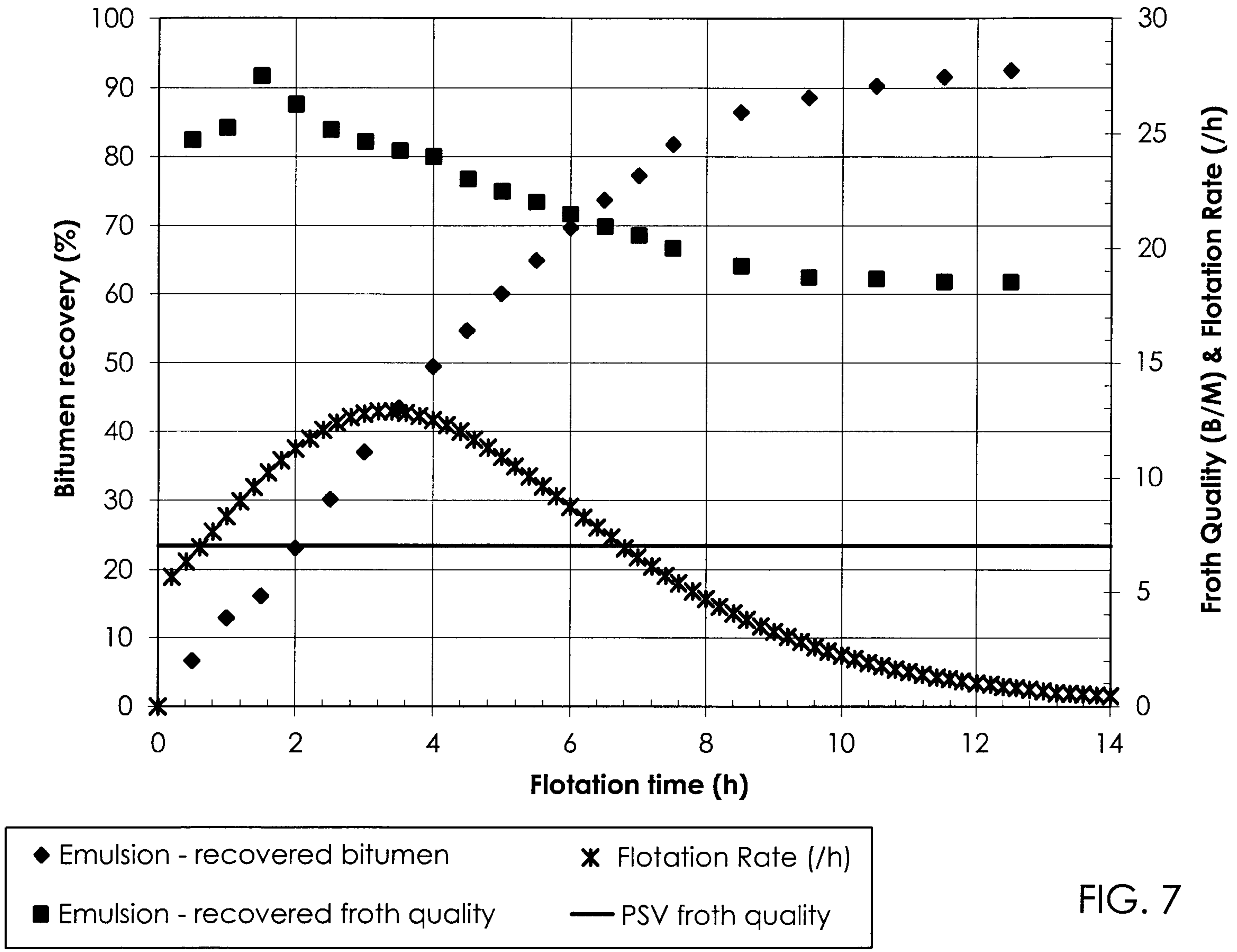
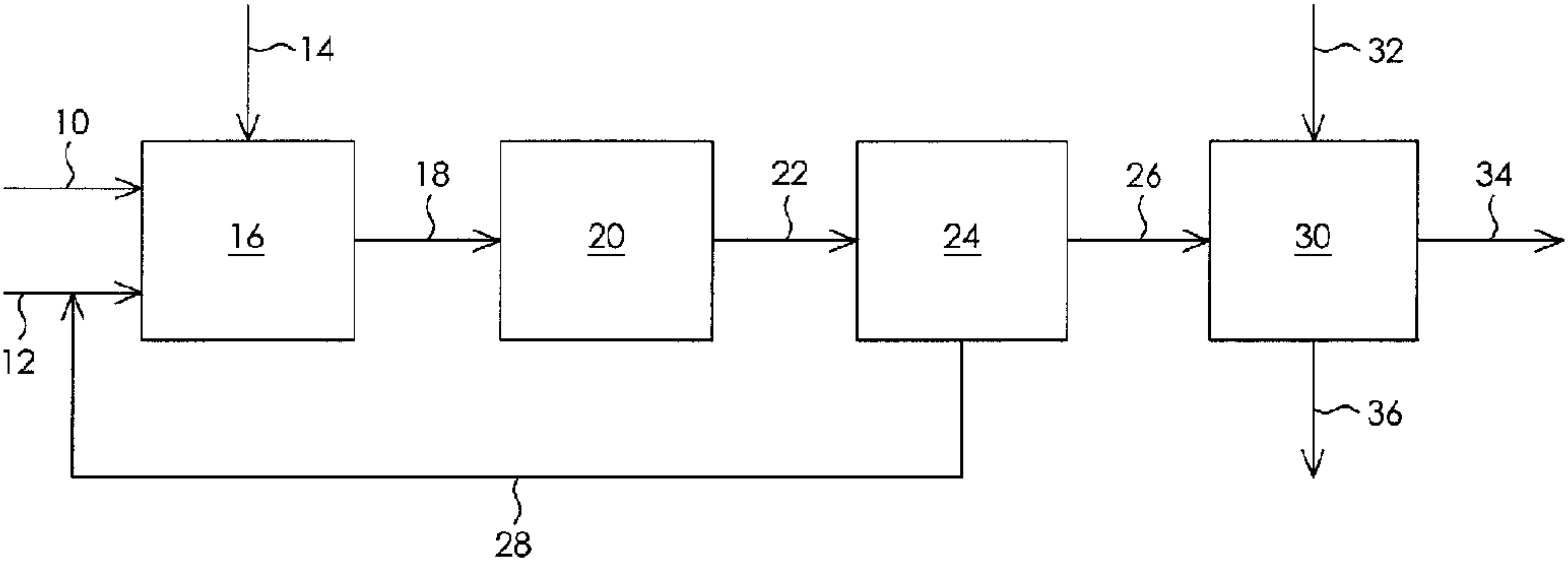


FIG. 6



100
90
80
70
60
50
40
30
20
10
0
Bitumen recovery (%)
0
2
4
6
8
10
12
14
Flotation time (h)
30
25
20
15
10
5
0
Froth Quality (B/M) & Flotation Rate (/h)
Emulsion - recovered bitumen
Emulsion - recovered froth quality
Flotation Rate (/h)
PSV froth quality

FIG. 7



10
12
14
16
18
20
22
24
26
28
30
32
34
36