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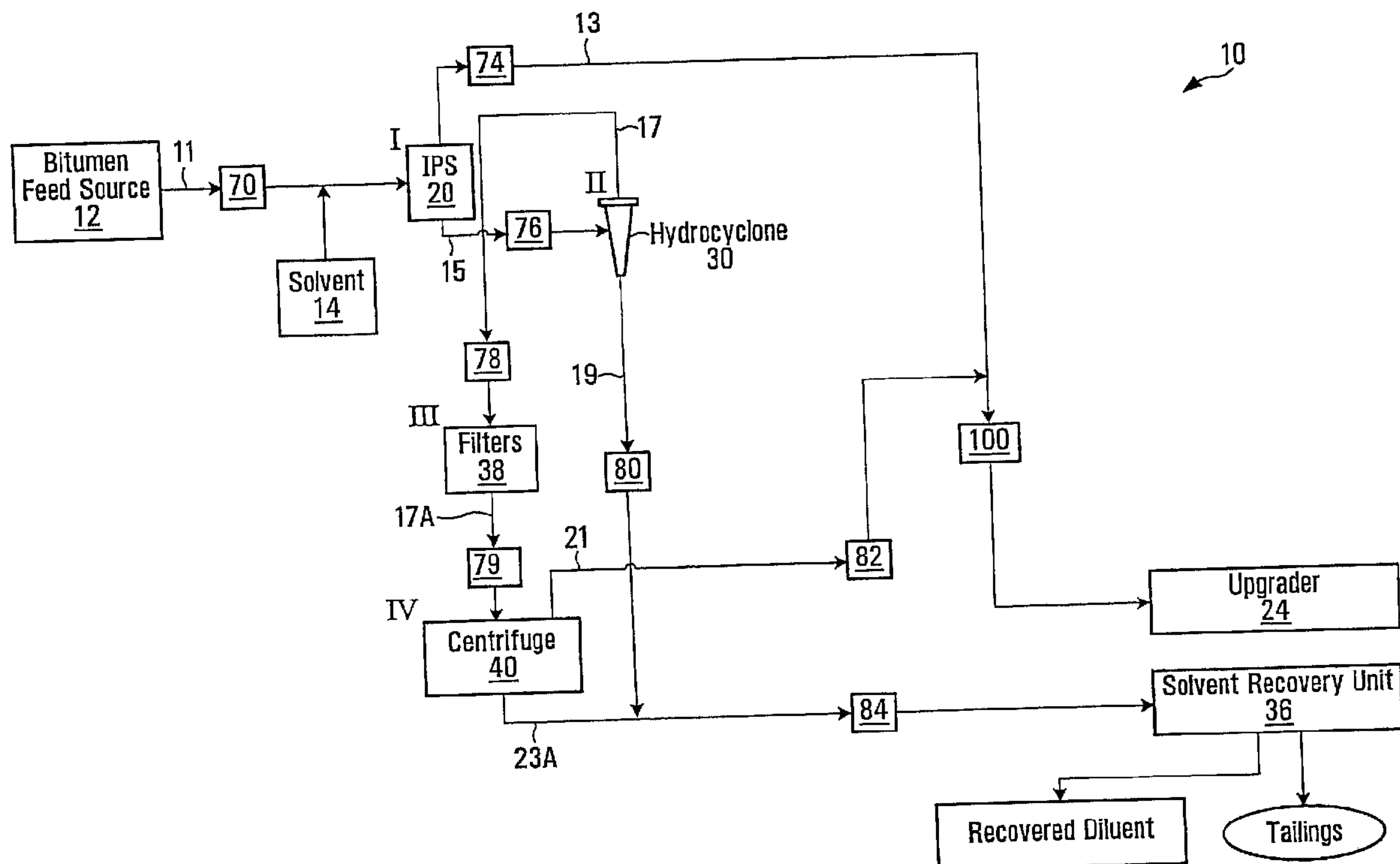
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(54) **Titre : SYSTEME ET PROCEDE DE CONCENTRATION DES HYDROCARBURES DANS UNE CHARGE D'ALIMENTATION DE BITUME**

(54) **Title: SYSTEM AND PROCESS FOR CONCENTRATING HYDROCARBONS IN A BITUMEN FEED**



(57) Abrégé/Abstract:

A system and process for concentrating hydrocarbon in a bitumen feed comprising bitumen, water and solids. The system comprises an inclined plate separator, a hydrocarbon cyclone and a centrifuge. The inclined plate separator separates the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a first bitumen concentration greater than that of the first underflow stream. The hydrocarbon cyclone separates the first underflow stream into a second overflow stream and a second underflow stream. The centrifuge separates the second overflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a third bitumen concentration that is greater than that of the third underflow stream.

-31-

ABSTRACT

A system and process for concentrating hydrocarbon in a bitumen feed comprising bitumen, water and solids. The system comprises an inclined plate separator, a hydrocarbon cyclone and a centrifuge. The inclined plate separator separates the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a first bitumen concentration greater than that of the first underflow stream. The hydrocarbon cyclone separates the first underflow stream into a second overflow stream and a second underflow stream. The centrifuge separates the second overflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a third bitumen concentration that is greater than that of the third underflow stream.

-1-

SYSTEM AND PROCESS FOR CONCENTRATING HYDROCARBONS IN A BITUMEN FEED

FIELD OF THE INVENTION

5 The present invention relates generally to a system and process for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids.

BACKGROUND OF THE INVENTION

10 Oil sands deposits are found in over seventy countries throughout the world. However, a substantial portion of these deposits are located in the Alberta oil sands. In fact, Alberta's oil sands deposits contain the largest known reserve of oil in the world. The vast quantities of oil in these deposits creates a tremendous incentive to develop and improve upon techniques and systems for recovering them.

15 Oil sands are a geological formation, which are also known as tar sands or bituminous sands. Oil sands deposits are primarily composed of solids (generally mineral components such as clay, silt and sand) plus bitumen and water. The bitumen content typically constitutes up to about 21 wt. % of the bitumen-bearing formation material, with the remainder of the formation material composed of about 70 to 85 wt. % solids and about 4 to 10 wt. % water. The solids content typically includes clay and silt ranging from about 5 to 50 wt. %. Technically speaking, the bitumen is neither oil nor tar, but a semisolid form of oil which will not flow toward producing wells under
20 normal conditions, making it difficult and expensive to produce.

Oil sand deposits are mined using strip mining techniques or persuaded to flow into producing wells by techniques such as steam assisted gravity drainage (SAGD) or cyclic steam stimulation (CSS) which reduce the bitumen's viscosity with steam, solvents or a combination of steam and solvents.

25 In order to produce an appropriate quality of bitumen-based product for use by a refinery, the hydrocarbons in the bitumen-bearing formation material removed from oil sands deposits need to be concentrated. Concentrating the hydrocarbon content of

-2-

a bitumen-bearing material (also known as bitumen recovery) is typically carried out through primary and secondary treatment processes that are well known in the art.

In conventional primary treatment facilities, the bitumen-bearing formation material is processed to produce a bitumen-enriched froth stream, which typically has a bitumen content of about 50 to 60 wt. %, a solids content of about 10 to 15 wt. % and a water content of about 30 to 40 wt. %. The bitumen-enriched froth stream that is produced through primary treatment is typically transported to a secondary treatment facility to increase its hydrocarbon concentration further in order to make it suitable for processing by an upgrader or specialized refinery facility. In order to make use of the bitumen-enriched froth stream in an upgrader or refinery, secondary treatment facilities process the stream in order to produce a hydrocarbon-rich product having a hydrocarbon concentration typically in the range of at least about 90% to 97% wt. % or more. Various techniques may be used to enhance the hydrocarbon concentration of the bitumen-enriched froth stream produced by primary treatment processes, examples of which can be found in Canadian Patent Nos. 873,854, 882,667 and 2,400,258.

Although various treatment processes exist to produce a bitumen-enriched product suitable for use by an upgrader or refinery, there continues to be a need for further treatment processes and systems that offer enhancements or alternatives to the manner in which a bitumen-enriched froth stream from primary treatment is processed.

SUMMARY OF THE INVENTION

In one aspect of the present invention there is provided a process for concentrating hydrocarbon in a bitumen feed comprising bitumen, water and solids. With this process the bitumen feed is separated, in an inclined plate separator, into a first overflow stream and a first underflow stream, with the first overflow stream having a first bitumen concentration greater than that of the first underflow stream. The first underflow stream is processed by a first cyclone, which separates the first underflow stream into a second overflow stream and a second underflow stream. The second overflow stream is processed by a first centrifuge, which separates the second overflow stream into a third overflow stream and a third underflow stream. With this

-3-

process, the third overflow stream has a third bitumen concentration that is greater than that of the third underflow stream. In addition, the first overflow stream and the third overflow stream each are suitable for use by an upgrader.

5 In another aspect of the present invention, there is provided a system for concentrating hydrocarbon in a bitumen feed comprising bitumen, water and solids. The system comprises means for separating, in an inclined plate separator, the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a first bitumen concentration greater than that of the first underflow stream. The system also comprises means for separating, in a first cyclone, the first underflow stream into
10 a second overflow stream and a second underflow stream, the second overflow stream having a second bitumen concentration greater than that of the second underflow stream. In addition, the system comprises means for separating, in a first centrifuge, the second overflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a third bitumen concentration that is greater than that
15 of the third underflow stream.

In yet another aspect of the present invention, there is provided a system for concentrating hydrocarbon in a bitumen feed comprising bitumen, water and solids, the system comprising an inclined plate separator, a cyclone and a centrifuge. With this aspect, the inclined plate separator separates the bitumen feed into a first overflow
20 stream and a first underflow stream, the first overflow stream having a first bitumen concentration greater than that of the first underflow stream. The first cyclone separates the first underflow stream into a second overflow stream and a second underflow stream. The first centrifuge separates the second overflow stream into a third overflow stream and a third underflow stream, wherein the first overflow stream and the third overflow
25 stream each comprise about or less than about 1.0 wt. % solids.

In a further aspect of the present invention, there is provided a process for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids. The process may include:

-3a-

separating, in an inclined plate separator, the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

5 separating, in a first cyclone, the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

10 separating, in a second cyclone, the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

15 separating, in a first gravity settler, a combination of the third overflow stream with the first overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, wherein the first overflow stream, the third overflow stream, the fourth overflow stream or a combination thereof is suitable for use by an upgrader; and

20 recycling a first portion of the fourth underflow stream upstream of the inclined plate separator.

The process may further include combining a second portion of the fourth underflow stream with the first underflow stream.

25 The process may further include recycling the second overflow stream upstream of the inclined plate separator.

30 The process may further include treating the bitumen feed with a solvent, a chemical additive or a combination thereof prior to the separating step in the inclined plate separator.

-3b-

In a further aspect of the present invention there is provided a process for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids. The process may include:

5 separating, in an inclined plate separator, the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

10 separating, in a first cyclone, the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

15 separating, in a second cyclone, the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

20 separating, in a centrifuge, a combination of the second overflow stream with the third overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream;

25 combining the fourth overflow stream with the first overflow stream, wherein the first overflow stream, the fourth overflow stream or a combination thereof is suitable for use by an upgrader;

30 separating a portion of the combination of the fourth overflow stream and the first overflow stream, in a gravity settler, into a fifth overflow stream suitable for use by the upgrader and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream; and

 recycling a first portion of the fifth underflow stream upstream of the inclined plate separator.

-3c-

The process may further include filtering the combination of the second overflow stream with the third overflow stream before the separating step in the centrifuge.

5 The process may further include combining a second portion of the fifth underflow stream with the second overflow stream, or with the combination of the second overflow stream with the third overflow stream before the separating step in the centrifuge, before filtering or a combination thereof.

10 The process may further include treating the bitumen feed with a solvent, a chemical additive or a combination thereof prior to the separating step in the inclined plate separator.

In a further aspect of the present invention, there is provided a process for
15 concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids.
The process may include:

separating, in an inclined plate separator, the bitumen feed into a first
overflow stream and a first underflow stream, the first overflow stream having a
20 bitumen concentration greater than that of the first underflow stream;

separating, in a first cyclone, the first underflow stream into a second overflow
stream and a second underflow stream, the second overflow stream having a bitumen
concentration greater than that of the second underflow stream;

25 separating, in a second cyclone, the second underflow stream into a third
overflow stream and a third underflow stream, the third overflow stream having a
bitumen concentration greater than that of the third underflow stream;

30 separating, in a centrifuge, the third overflow stream into a fourth overflow
stream and a fourth underflow stream, the fourth overflow stream having a bitumen
concentration greater than that of the fourth underflow stream, wherein the fourth

-3d-

overflow stream, the first overflow stream or a combination thereof is suitable for use by an upgrader;

5 separating a combination of a first portion of the fourth overflow stream and the first overflow stream, in a gravity settler, into a fifth overflow stream suitable for use by the upgrader and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream; and

10 recycling a first portion of the fifth underflow stream upstream of the inclined plate separator.

The process may further include combining a second portion of the fifth underflow stream with the first underflow stream.

15 The process may further include combining a third portion of the fifth underflow stream with the third overflow stream.

20 The process may further include filtering the third overflow stream or a combination of the third overflow stream with the third portion of the fifth underflow stream before the separating step in the centrifuge.

The process may further include recycling the second overflow stream upstream of the inclined plate separator.

25 The process may further include treating the bitumen feed with a solvent, a chemical additive or a combination thereof prior to the separating step in the inclined plate separator.

30 In a further aspect of the present invention, there is provided a process for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids. The process may include:

-3e-

separating, in an inclined plate separator, the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

5 separating, in a first cyclone, the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

10 separating, in a second cyclone, the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

15 separating, in a centrifuge, the second overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, wherein each of the first overflow stream and the fourth overflow stream is suitable for use by an upgrader;

20 separating a combination of a first portion of the fourth overflow stream and a first portion of the first overflow stream, in a gravity settler, into a fifth overflow stream suitable for use by the upgrader and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream;

25 recycling the third overflow stream upstream of the inclined plate separator;
and

recycling a first portion of the fifth underflow stream upstream of the inclined plate separator.

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The process may further include combining a second portion of the fifth underflow stream with the second overflow stream to form a combined stream.

-3f-

The process may further include filtering the second overflow stream or the combined stream before the separating step in the centrifuge.

- 5 The process may further include treating the bitumen feed with a solvent, a chemical additive or a combination thereof prior to the separating step in the inclined plate separator.

10 In yet a further aspect of the present invention, there is provided a process for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids. The process may include:

15 separating, in an inclined plate separator, the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

20 separating, in a first cyclone, the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

25 separating, in a second cyclone, the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

30 separating, in a first centrifuge, the second overflow stream and the third overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream;

35 separating, in a second centrifuge, the fourth overflow stream into a fifth overflow stream and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream;

-3g-

combining the fifth overflow stream with the first overflow stream, wherein the first overflow stream, the fifth overflow stream or a combination thereof is suitable for use by an upgrader;

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separating the combination of the fifth overflow stream and the first overflow stream, in a gravity settler, into a sixth overflow stream suitable for use by the upgrader and a sixth underflow stream, the sixth overflow stream having a bitumen concentration greater than that of the sixth underflow stream; and

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recycling a first portion of the sixth underflow stream upstream of the inclined plate separator.

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The process may further include filtering the fourth overflow stream before the separating step in the second centrifuge.

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The process may further include combining a second portion of the sixth underflow stream with the second underflow stream before the separating step in the second cyclone.

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The process may further include combining a third portion of the sixth underflow stream with the second overflow stream and the third overflow stream before the separating step in the first centrifuge.

30

The process may further include treating the bitumen feed with a solvent, a chemical additive or a combination thereof to form a treated bitumen feed prior to the separating step in the inclined plate separator.

The process may further include combining a portion of the treated bitumen feed with the combination of the second overflow stream and the third overflow stream.

-3h-

The process may further include combining a second solvent with the first underflow stream.

5 The process may further include combining a third solvent with the second underflow stream.

10 The process may further include combining a fourth solvent with the combination of the third portion of the sixth underflow stream with the second overflow stream and the third overflow stream before the separating step in the first centrifuge.

The process may further include combining a fifth solvent with the combination of the fifth overflow stream with the first overflow stream.

15 In a further aspect of the present invention, there is provided a process for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids. The process may include:

20 separating, in an inclined plate separator, the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

25 separating, in a first cyclone, the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

separating, in a second cyclone, the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

30 combining the second overflow stream with the third overflow stream to form a combined overflow stream; and

-3i-

separating, in a first centrifuge, the combined overflow stream to produce a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream.

5 The process may further include combining the fourth overflow stream with the first overflow stream, wherein the first overflow stream, the fourth overflow stream or a combination thereof is suitable for use by an upgrader.

10 The process may further include filtering the combined overflow stream before the separating step in the first centrifuge.

The process may further include combining a portion of the bitumen feed with the second overflow stream or the combined overflow stream before the filtering step, the separating step in the first centrifuge or a combination thereof.

15 The process may further include:

20 separating, in a second centrifuge, the fourth overflow stream to produce a fifth overflow stream and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream; and

25 combining the fifth overflow stream with the first overflow stream, wherein the first overflow stream, the fifth overflow stream or a combination thereof is suitable for use by an upgrader.

The process may further include filtering the fourth overflow stream before the separating step in the second centrifuge.

30 The process may further include the fifth overflow stream having about 1.2 wt. % solids or less.

-3j-

The process may further include the fifth overflow stream having about 1.0 wt. % solids or less.

5 The process may further include the fifth overflow stream having about 0.4 wt. % to about 0.8 wt. % solids.

The process may further include the fifth overflow stream having about 0.3 wt. % to about 0.6 wt. % solids.

10 The process may further include the fifth overflow stream having about 0.5 wt. % solids or less.

The bitumen concentration of the fifth overflow stream may be about 95 wt. % or more.

15 The bitumen concentration of the fifth overflow stream may be about 98 wt. % or more.

20 The process may further include treating the bitumen feed with a solvent, a chemical additive or a combination thereof prior to the separating step in the inclined plate separator.

In a further aspect of the present invention there is provided a process for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids.

25 The process may include:

separating, in an inclined plate separator, the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

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-3k-

separating, in a first cyclone, the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

5 separating, in a second cyclone, the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream, and combining the third overflow stream with the first underflow stream;

10 separating, in a third cyclone, the third underflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, and combining the fourth overflow stream with the second underflow stream;

15 separating, in a centrifuge, the first overflow stream into a fifth overflow stream and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream; and

20 combining the fifth overflow stream with the first overflow stream, wherein the first overflow stream, the fifth overflow stream or a combination thereof is suitable for use by an upgrader.

25 The process may further include processing the bitumen feed in a grinder, treating the bitumen feed with a solvent, or a combination thereof prior to the separating step in the inclined plate separator.

In a further aspect of the present invention, there is provided a process for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the process comprising:

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-31-

separating, in an inclined plate separator, the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

- 5 separating, in a cyclone, the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

10 filtering the second overflow stream to form a filtered overflow stream;

separating, in a first centrifuge, the filtered overflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream; and

- 15 combining the third overflow stream with the first overflow stream, wherein the first overflow stream, the third overflow stream or a combination thereof is suitable for use by an upgrader.

20 The process may further include separating, in a second centrifuge, the second overflow stream into a fourth overflow stream and a fourth underflow stream prior to the filtering step, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, wherein the fourth overflow stream is filtered in the filtering step.

- 25 The process may further include treating the bitumen feed with a solvent prior to the separating step in the inclined plate separator.

30 The process may further include the third overflow stream having about 1.2 wt. % solids or less.

The process may further include the third overflow stream having about 1.0 wt. % solids or less.

-3m-

The process may further include the third overflow stream having about 0.4 wt. % to about 0.8 wt. % solids.

- 5 The process of any one of claims 45-47 wherein the third overflow stream has about 0.3 wt. % to about 0.6 wt. % solids.

The process may further include the third overflow stream having about 0.5 wt. % solids or less.

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The bitumen concentration of the third overflow stream may be about 95 wt. % or more.

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The bitumen concentration of the third overflow stream may be about 98 wt. % or more.

In a further aspect of the present invention, there is provided a process for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids. The process may include:

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separating, in an inclined plate separator, the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

25

separating, in a first cyclone, the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

30

separating, in a second cyclone, the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

-3n-

combining the second overflow stream with the third overflow stream to form a combined overflow stream;

filtering the combined overflow stream to form a filtered overflow stream;

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separating, in a first centrifuge, the filtered overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream; and

10

combining the fourth overflow stream with the first overflow stream, wherein the first overflow stream, the fourth overflow stream or a combination thereof is suitable for use by an upgrader.

15

The process may further include separating, in a second centrifuge, the combined overflow stream into a fifth overflow stream and a fifth underflow stream prior to the filtering step, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream, wherein the fifth overflow stream is filtered in the filtering step.

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The process may further include treating the bitumen feed with a solvent prior to the separating step in the inclined plate separator.

In a further aspect of the present invention, there is provided a process for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids.

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The process may include:

separating, in an inclined plate separator, the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

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-30-

separating, in a cyclone, the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

5 separating, in a first centrifuge, the second overflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

10 filtering the third overflow stream to form a filtered overflow stream;

separating, in a second centrifuge, the filtered overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream; and

15 combining the fourth overflow stream with the first overflow stream, wherein the first overflow stream, the fourth overflow stream or a combination thereof is suitable for use by an upgrader.

20 The process may further include treating the bitumen feed with a solvent prior to the separating step in the inclined plate separator.

The solvent, the second solvent, the third solvent, the fourth solvent, or the fifth solvent may include a liquid hydrocarbon.

25 The liquid hydrocarbon may include naphtha.

The first overflow stream may have about 1.2 wt. % solids or less.

30 The first overflow stream may have about 1.0 wt. % solids or less.

The process of any one of claims 1 to 61 wherein the first overflow stream has about 0.9 wt. % to about 1.5 wt. % water.

-3p-

The bitumen concentration in the first overflow stream may be about 98 wt. % or more.

5 In a further aspect of the present invention there is provided a system for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids. The system may include:

10 first separation means for a low gravitational separation of the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

15 second separation means for a first high gravitational separation of the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream, the first high gravitational separation having a higher force than the low gravitational separation;

20 third separation means for a second high gravitational separation of the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream, the second high gravitational separation having a higher force than the low gravitational separation;

25 fourth separation means for a gravitational separation of a combination of the third overflow stream with the first overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, wherein the first overflow stream, the third overflow stream, the fourth overflow stream or a combination thereof is suitable
30 for use by an upgrader, the gravitational separation of the fourth separation means having a lower force than the low gravitational separation; and

-3q-

first recycling means for recycling a first portion of the fourth underflow stream upstream of the inclined plate separator.

5 The system may further include combining means for combining a second portion of the fourth underflow stream with the first underflow stream.

The system may further include second recycling means for recycling the second overflow stream upstream of the first separation means.

10 The system may further include treating means for treating the bitumen feed with a solvent, a chemical additive or a combination thereof upstream of the first separation means.

15 In a further aspect of the present invention there is provided a system for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids. The system may include:

20 first separation means for a low gravitational separation of the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

25 second separation means for a first high gravitational separation of the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream, the first high gravitational separation having a higher force than the low gravitational separation;

30 third separation means for a second high gravitational separation of the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream, the second high gravitational separation having a higher force than the low gravitational separation;

-3r-

fourth separation means for a gravitational separation of a combination of the second overflow stream with the third overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, the gravitational separation of the fourth separation means having a higher force than each of the first and the second high gravitational separations;

combining means for combining the fourth overflow stream with the first overflow stream, wherein the first overflow stream, the fourth overflow stream or a combination thereof is suitable for use by an upgrader;

fifth separation means for a gravitational separation of a portion of the combination of the fourth overflow stream and the first overflow stream into a fifth overflow stream suitable for use by the upgrader and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream, the gravitational separation of the fifth separation means having a lower force than the low gravitational separation; and

recycling means for recycling a first portion of the fifth underflow stream upstream of the first separation means.

The system may further include filtering means for filtering the combination of the second overflow stream with the third overflow stream upstream of the fourth separation means.

The system may further include combining means for combining a second portion of the fifth underflow stream with the second overflow stream, or with the combination of the second overflow stream with the third overflow stream upstream of the fourth separation means, upstream of the filtering means or a combination thereof.

-3s-

The system may further include treating means for treating the bitumen feed with a solvent, a chemical additive or a combination thereof upstream of the first separation means.

5 In a further aspect of the present invention, there is provided a system for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids. The system may include:

10 first separation means for a low gravitational separation of the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

15 second separation means for a first high gravitational separation of the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream, the first high gravitational separation having a higher force than the low gravitational separation;

20 third separation means for a second high gravitational separation of the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream, the second high gravitational separation having a higher force than the low gravitational separation;

25 fourth separation means for a gravitational separation of the third overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, wherein the fourth overflow stream, the first overflow stream or a combination thereof is suitable for use by an upgrader, the gravitational separation of
30 the fourth separation means having a higher force than each of the first and the second high gravitational separations;

-3t-

5 fifth separation means for a gravitational separation of a combination of a first portion of the fourth overflow stream and the first overflow stream into a fifth overflow stream suitable for use by the upgrader and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream, the gravitational separation of the fifth separation means having a lower force than the low gravitational separation; and

10 first recycling means for recycling a first portion of the fifth underflow stream upstream of the first separation means.

The system may further include first combining means for combining a second portion of the fifth underflow stream with the first underflow stream.

15 The system may further include second combining means for combining a third portion of the fifth underflow stream with the third overflow stream.

20 The system may further include filtering means for filtering the third overflow stream or a combination of the third overflow stream with the third portion of the fifth underflow stream upstream of the fourth separation means.

The system may further include second recycling means for recycling the second overflow stream upstream of the first separation means.

25 The system may further include treating means for treating the bitumen feed with a solvent, a chemical additive or a combination thereof upstream of the first separation means.

30 In a further aspect of the present invention, there is provided a system for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids.
The system may include:

-3u-

first separation means for a low gravitational separation of the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

5 second separation means for a first high gravitational separation of the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream, the first high gravitational separation having a higher force than the low gravitational separation;

10

third separation means for a second high gravitational separation of the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream, the second high gravitational separation having a higher force than the low gravitational separation;

15

fourth separation means for a gravitational separation of the second overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, wherein each of the first overflow stream and the fourth overflow stream is suitable for use by an upgrader, the gravitational separation of the fourth separation means having a higher force than each of the first and the second high gravitational separations;

20

fifth separation means for a gravitational separation of a combination of a first portion of the fourth overflow stream and a first portion of the first overflow stream into a fifth overflow stream suitable for use by the upgrader and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream, the gravitational separation of the fifth separation means having a lower force than the low gravitational separation;

25

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-3v-

first recycling means for recycling the third overflow stream upstream of the first separation means; and

5 second recycling means for recycling a first portion of the fifth underflow stream upstream of the first separation means.

The system may further include combining means for combining a second portion of the fifth underflow stream with the second overflow stream to form a combined stream.

10 The system may further include filtering means for filtering the second overflow stream or the combined stream upstream of the fourth separation means.

The system may further include treating means for treating the bitumen feed with a solvent, a chemical additive or a combination thereof upstream of the first separation means.

15 In a further aspect of the present invention, there is provided a system for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids.

20 The system may include:

first separation means for a low gravitational separation of the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

25 second separation means for a first high gravitational separation of the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream, the first high gravitational separation having a higher force

30 than the low gravitational separation;

-3w-

third separation means for a second high gravitational separation of the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream, the second high gravitational separation having a higher force than the low gravitational separation;

fourth separation means for a gravitational separation of the second overflow stream and the third overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, the gravitational separation of the fourth separation means having a higher force than each of the first and the second high gravitational separations;

fifth separation means for a gravitational separation of the fourth overflow stream into a fifth overflow stream and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream, the gravitational separation of the fifth separation means having a higher force than each of the first and the second high gravitational separations;

combining means for combining the fifth overflow stream with the first overflow stream, wherein the first overflow stream, the fifth overflow stream or a combination thereof is suitable for use by an upgrader;

sixth separation means for a gravitational separation of the combination of the fifth overflow stream and the first overflow stream into a sixth overflow stream suitable for use by the upgrader and a sixth underflow stream, the sixth overflow stream having a bitumen concentration greater than that of the sixth underflow stream, the gravitational separation of the sixth separation means having a lower force than the low gravitational separation; and

recycling means for recycling a first portion of the sixth underflow stream upstream of the first separation means.

-3x-

The system may further include filtering means for filtering the fourth overflow stream upstream of the fifth separation means.

5 The system may further include first combining means for combining a second portion of the sixth underflow stream with the second underflow stream upstream of the third separation means.

10 The system may further include second combining means for combining a third portion of the sixth underflow stream with the second overflow stream and the third overflow stream upstream of the fourth separation means.

15 The system may further include treating means for treating the bitumen feed with a solvent, a chemical additive or a combination thereof to form a treated bitumen feed upstream of the first separation means.

20 The system may further include third combining means for combining a portion of the treated bitumen feed with the combination of the second overflow stream and the third overflow stream.

The system may further include fourth combining means for combining a second solvent with the first underflow stream.

25 The system may further include fifth combining means for combining a third solvent with the second underflow stream.

30 The system may further include sixth combining means for combining a fourth solvent with the combination of the third portion of the sixth underflow stream with the second overflow stream and the third overflow stream upstream of the fourth separation means.

-3y-

The system may further include seventh combining means for combining a fifth solvent with the combination of the fifth overflow stream with the first overflow stream.

- 5 In a further aspect of the present invention there is provided a system for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids. The system may include:

10 first separation means for a low gravitational separation of the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

15 second separation means for a first high gravitational separation of the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream, the first high gravitational separation having a higher force than the low gravitational separation;

20 third separation means for a second high gravitational separation of the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream, the second high gravitational separation having a higher force than the low gravitational separation;

25 first combining means for combining the second overflow stream with the third overflow stream to form a combined overflow stream; and

30 fourth separation means for a first gravitational separation of the combined overflow stream to produce a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, the first gravitational separation of the fourth separation

-3z-

means having a higher force than each of the first and the second high gravitational separations.

5 The system may further include second combining means for combining the fourth overflow stream with the first overflow stream, wherein the first overflow stream, the fourth overflow stream or a combination thereof is suitable for use by an upgrader.

10 The system may further include filtering means for filtering the combined overflow stream upstream of the fourth separation means.

The system may further include third combining means for combining a portion of the bitumen feed with the second overflow stream or the combined overflow stream upstream of the filtering means, the third separation means or a combination thereof.

15 The system may further include fifth separation means for a second gravitational separation of the fourth overflow stream to produce a fifth overflow stream and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream, the second gravitational separation of the fifth separation means having a higher force than each of the first and the second high
20 gravitational separations.

The second gravitational separation of the fifth separation means may have a higher force than the first gravitational separation of the fourth separation means.

25 The system may further include filtering means for filtering the fourth overflow stream upstream of the fifth separation means.

30 The system may further include second combining means for combining the fifth overflow stream with the first overflow stream, wherein the first overflow stream, the fifth overflow stream or a combination thereof is suitable for use by an upgrader.

-3aa-

The system may further include treating means for treating the bitumen feed with a solvent, a chemical additive or a combination thereof upstream of the first separation means.

5 In a further aspect of the present invention, there is provided a system for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids. The system may include:

10 first separation means for a low gravitational separation of the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

15 second separation means for a first high gravitational separation of the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream, the first high gravitational separation having a higher force than the low gravitational separation;

20 third separation means for a second high gravitational separation of the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream, and combining the third overflow stream with the first underflow stream, the second high gravitational separation having a higher force than the low gravitational separation;

25 fourth separation means for a third high gravitational separation of the third underflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, and combining the fourth overflow stream with the second underflow stream, the third high gravitational separation having a higher force than the low gravitational separation;

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-3bb-

5 fifth separation means for a gravitational separation of the first overflow stream into a fifth overflow stream and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream, the gravitational separation of the fifth separation means having a higher force than each of the first, the second and the third high gravitational separations; and

10 combining means for combining the fifth overflow stream with the first overflow stream, wherein the first overflow stream, the fifth overflow stream or a combination thereof is suitable for use by an upgrader.

15 The system may further include grinding means for grinding the bitumen feed, treating means for treating the bitumen feed with a solvent, or a combination thereof upstream of the first separation means.

20 In a further aspect of the present invention, there is provided a system for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids. The system may include:

25 first separation means for a low gravitational separation of the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

30 second separation means for a high gravitational separation of the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream, the high gravitational separation having a higher force than the low gravitational separation;

35 filtering means for filtering the second overflow stream to form a filtered overflow stream;

-3cc-

third separation means for a gravitational separation of the filtered overflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream, the gravitational separation of the third separation means having a higher force than the high gravitational separation; and

combining means for combining the third overflow stream with the first overflow stream, wherein the first overflow stream, the third overflow stream or a combination thereof is suitable for use by an upgrader.

The system may further include fourth separation means upstream of the filtering means for a gravitational separation of the second overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, the gravitational separation of the fourth separation means having a higher force than the high gravitational separation, wherein the fourth overflow stream is filtered by the filtering means.

The second separation means may include a first cyclone, a second cyclone and a centrifuge.

The system may further include treating means for treating the bitumen feed with a solvent upstream of the first separation means.

In a further aspect of the present invention, there is provided a system for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids. The system may include:

first separation means for a low gravitational separation of the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

-3dd-

5 second separation means for a first high gravitational separation of the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream, the first high gravitational separation having a higher force than the low gravitational separation;

10 third separation means for a second high gravitational separation of the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream, the second high gravitational separation having a higher force than the low gravitational separation;

15 first combining means for combining the second overflow stream with the third overflow stream to form a combined overflow stream;

filtering means for filtering the combined overflow stream to form a filtered overflow stream;

20 fourth separation means for a gravitational separation of the filtered overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, the gravitational separation of the fourth separation means having a higher force than each of the first and the second high gravitational separations; and

25 second combining means for combining the fourth overflow stream with the first overflow stream, wherein the first overflow stream, the fourth overflow stream or a combination thereof is suitable for use by an upgrader.

30 The system may further include fifth separation means upstream of the filtering means for a gravitational separation of the combined overflow stream into a fifth overflow stream and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream, the gravitational

-3ee-

separation of the fifth separation means having a higher force than each of the first and the second high gravitational separations, wherein the fifth overflow stream is filtered by the filtering means.

5 The second separation means may include a first cyclone and a second cyclone.

The system may further include treating means for treating the bitumen feed with a solvent upstream of the first separation means.

10 In a further aspect of the present invention, there is provided a system for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids. The system may include:

15 first separation means for a low gravitational separation of the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

20 second separation means for a high gravitational separation of the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream, the high gravitational separation having a higher force than the low gravitational separation;

25 third separation means for a first gravitational separation of the second overflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream, the first gravitational separation of the third separation means having a higher force than the high gravitational separation;

30 filtering means for filtering the third overflow stream to form a filtered overflow stream;

-3ff-

fourth separation means for a second gravitational separation of the filtered overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, the second gravitational separation of the fourth separation means having a higher force than the high gravitational separation; and

combining means for combining the fifth overflow stream with the first overflow stream, wherein the first overflow stream, the fifth overflow stream or a combination thereof is suitable for use by an upgrader.

The second separation means may include a first cyclone and a second cyclone.

The system may further include treating means for treating the bitumen feed with a solvent upstream of the first separation means.

In a further aspect of the present invention, there is provided an apparatus for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids. The apparatus may include:

an inclined plate separator for separating the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

a first cyclone for separating the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

a second cyclone for separating the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

-3gg-

5 a first gravity settler for separating a combination of the third overflow stream with the first overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, wherein the first overflow stream, the third overflow stream, the fourth overflow stream or a combination thereof is suitable for use by an upgrader; and

10 a first recycle path for recycling a first portion of the fourth underflow stream upstream of the inclined plate separator.

The apparatus may further include a modulator for combining a second portion of the fourth underflow stream with the first underflow stream.

15 The apparatus may further include a second recycle path for recycling the second overflow stream upstream of the inclined plate separator.

20 The apparatus may further include a treater for treating the bitumen feed with a solvent, a chemical additive or a combination thereof upstream of the inclined plate separator.

In a further aspect of the present invention, there is provided an apparatus for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids. The apparatus may include:

25 an inclined plate separator for separating the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

30 a first cyclone for separating the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

-3hh-

a second cyclone for separating the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

5 a centrifuge for separating a combination of the second overflow stream with the third overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream;

10 a first modulator for combining the fourth overflow stream with the first overflow stream, wherein the first overflow stream, the fourth overflow stream or a combination thereof is suitable for use by an upgrader;

15 a gravity settler for separating a portion of the combination of the fourth overflow stream and the first overflow stream into a fifth overflow stream suitable for use by the upgrader and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream; and

20 a recycle path for recycling a first portion of the fifth underflow stream upstream of the inclined plate separator.

The apparatus may further include a filter for filtering the combination of the second overflow stream with the third overflow stream upstream of the centrifuge.

25 The apparatus may further include a second modulator for combining a second portion of the fifth underflow stream with the second overflow stream, or with the combination of the second overflow stream with the third overflow stream upstream of the centrifuge, upstream of the filter or a combination thereof.

30 The apparatus may further include a treater for treating the bitumen feed with a solvent, a chemical additive or a combination thereof upstream the inclined plate separator.

-3ii-

In a further aspect of the present invention, there is provided an apparatus for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids. The apparatus may include:

5 an inclined plate separator for separating the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

10 a first cyclone for separating the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

15 a second cyclone for separating the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

20 a centrifuge for separating the third overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, wherein the fourth overflow stream, the first overflow stream or a combination thereof is suitable for use by an upgrader;

25 a gravity settler for separating a combination of a first portion of the fourth overflow stream and the first overflow stream into a fifth overflow stream suitable for use by the upgrader and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream; and

30 a first recycle path for recycling a first portion of the fifth underflow stream upstream of the inclined plate separator.

The apparatus may further include a modulator for combining a second portion of the fifth underflow stream with the first underflow stream.

-3jj-

The apparatus may further include a modulator for combining a third portion of the fifth underflow stream with the third overflow stream.

- 5 The apparatus may further include a filter for filtering the third overflow stream or a combination of the third overflow stream with the third portion of the fifth underflow stream upstream of the centrifuge.

- 10 The apparatus may further include a second recycle path for recycling the second overflow stream upstream of the inclined plate separator.

- 15 The apparatus may further include a treater for treating the bitumen feed with a solvent, a chemical additive or a combination thereof upstream of the inclined plate separator.

- In a further aspect of the present invention, there is provided an apparatus for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids. The apparatus may include:

- 20 an inclined plate separator for separating the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

- 25 a first cyclone for separating the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

- 30 a second cyclone for separating the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

-3kk-

5 a centrifuge for separating the second overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, wherein each of the first overflow stream and the fourth overflow stream is suitable for use by an upgrader;

10 a gravity settler for separating a combination of a first portion of the fourth overflow stream and a first portion of the first overflow stream into a fifth overflow stream suitable for use by the upgrader and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream;

15 a first recycling path for recycling the third overflow stream upstream of the inclined plate separator; and

a second recycling path for recycling a first portion of the fifth underflow stream upstream of the inclined plate separator.

20 The apparatus may further include a modulator for combining a second portion of the fifth underflow stream with the second overflow stream to form a combined stream.

The apparatus may further include a filter for filtering the second overflow stream or the combined stream upstream of the centrifuge.

25 The apparatus may further include a treater for treating the bitumen feed with a solvent, a chemical additive or a combination thereof upstream of the inclined plate separator.

30 In a further aspect of the present invention, there is provided an apparatus for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids. The apparatus may include:

-311-

an inclined plate separator for separating the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

5 a first cyclone for separating the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

10 a second cyclone for separating the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

15 a first centrifuge for separating the second overflow stream and the third overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream;

20 a second centrifuge for separating the fourth overflow stream into a fifth overflow stream and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream;

25 a modulator for combining the fifth overflow stream with the first overflow stream, wherein the first overflow stream, the fifth overflow stream or a combination thereof is suitable for use by an upgrader;

30 a gravity settler for separating the combination of the fifth overflow stream and the first overflow stream into a sixth overflow stream suitable for use by the upgrader and a sixth underflow stream, the sixth overflow stream having a bitumen concentration greater than that of the sixth underflow stream; and

a first recycle path for recycling a first portion of the sixth underflow stream upstream of the inclined plate separator.

-3mm-

The apparatus may further include a filter for filtering the fourth overflow stream upstream of the second centrifuge.

- 5 The apparatus may further include a first modulator for combining a second portion of the sixth underflow stream with the second underflow stream upstream of the second cyclone.

- 10 The apparatus may further include a second modulator for combining a third portion of the sixth underflow stream with the second overflow stream and the third overflow stream upstream of the first centrifuge.

- 15 The apparatus may further include a treater for treating the bitumen feed with a solvent, a chemical additive or a combination thereof to form a treated bitumen feed upstream of the inclined plate separator.

- 20 The apparatus may further include a third modulator for combining a portion of the treated bitumen feed with the combination of the second overflow stream and the third overflow stream.

The apparatus may further include a fourth modulator for combining a second solvent with the first underflow stream.

- 25 The apparatus may further include a fifth modulator for combining a third solvent with the second underflow stream.

- 30 The apparatus may further include a sixth modulator for combining a fourth solvent with the combination of the third portion of the sixth underflow stream with the second overflow stream and the third overflow stream upstream of the first centrifuge.

The apparatus may further include a seventh modulator for combining a fifth solvent with the combination of the fifth overflow stream with the first overflow stream.

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In a further aspect of the present invention, there is provided an apparatus for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids.

The apparatus may include:

5

an inclined plate separator for separating the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

10

a first cyclone for separating the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

15

a second cyclone for separating the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

a first modulator for combining the second overflow stream with the third overflow stream to form a combined overflow stream; and

20

a first centrifuge for separating the combined overflow stream to produce a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream.

25

The apparatus may further include a second modulator for combining the fourth overflow stream with the first overflow stream, wherein the first overflow stream, the fourth overflow stream or a combination thereof is suitable for use by an upgrader.

30

The apparatus may further include a filter for filtering the combined overflow stream upstream of the first centrifuge.

-300-

The apparatus may further include a third modulator for combining a portion of the bitumen feed with the second overflow stream or the combined overflow stream upstream of the filter, the first centrifuge or a combination thereof.

5 The apparatus may further include a second centrifuge for separating the fourth overflow stream into a fifth overflow stream and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream.

10 The apparatus may further include a second modulator for combining the fifth overflow stream with the first overflow stream, wherein the fifth overflow stream, the first overflow stream or a combination thereof is suitable for use by an upgrader.

15 The apparatus may further include a filter for filtering the fourth overflow stream upstream of the second centrifuge.

20 The apparatus may further include a treater for treating the bitumen feed with a solvent, a chemical additive or a combination thereof upstream of the inclined plate separator.

In a further aspect of the present invention, there is provided an apparatus for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids. The apparatus may include:

25 an inclined plate separator for separating the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

30 a first cyclone for separating the first underflow stream into a second overflow stream and a second underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

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5

a second cyclone for separating the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream, and combining the third overflow stream with the first underflow stream;

10

a third cyclone for separating the third underflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, and combining the fourth overflow stream with the second underflow stream;

15

a centrifuge for separating the first overflow stream into a fifth overflow stream and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream; and

a modulator for combining the fifth overflow stream with the first overflow stream, wherein the first overflow stream, the fifth overflow stream or a combination thereof is suitable for use by an upgrader.

20

The apparatus may further include a grinder for processing the bitumen feed, a treater for treating the bitumen feed with a solvent, or a combination thereof upstream of the inclined plate separator.

25

In yet a further aspect of the present invention, there is provided an apparatus for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids. The apparatus may include:

30

an inclined plate separator for separating the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

-3qq-

a first cyclone for separating the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

5 a filter for filtering the second overflow stream to form a filtered overflow stream;

a centrifuge for separating the filtered overflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen
10 concentration greater than that of the third underflow stream; and

a modulator for combining the third overflow stream with the first overflow stream, wherein the first overflow stream, the third overflow stream or a combination thereof is suitable for use by an upgrader.

15

The apparatus may further include a second cyclone upstream of the filter for separating the second underflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, wherein the second overflow stream, the
20 fourth overflow stream or a combination thereof is filtered by the filter.

The apparatus may further include a treater for treating the bitumen feed with a solvent upstream of the inclined plate separator.

25 In a further aspect of the present invention, there is provided an apparatus for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids. The apparatus may include:

an inclined plate separator for separating the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen
30 concentration greater than that of the first underflow stream;

-3rr-

a first cyclone for separating the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

5 a second cyclone for separating the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

10 a first modulator for combining the second overflow stream with the third overflow stream to form a combined overflow stream;

a filter for filtering the combined overflow stream to form a filtered overflow stream;

15 a first centrifuge for separating the filtered overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream; and

20 a second modulator for combining the fourth overflow stream with the first overflow stream, wherein the first overflow stream, the fourth overflow stream or a combination thereof is suitable for use by an upgrader.

25 The apparatus may further include a second centrifuge upstream of the filter for separating the combined overflow stream into a fifth overflow stream and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream, wherein the fifth overflow stream is filtered by the filter.

30 The apparatus may further include a treater for treating the bitumen feed with a solvent upstream of the inclined plate separator.

-3ss-

In a further aspect of the present invention, there is provided an apparatus for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids. The apparatus may include:

5 an inclined plate separator for separating the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

10 a first cyclone for separating the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

15 a first centrifuge for separating the second overflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

 a filter for filtering the third overflow stream to form a filtered overflow stream;

20 a second centrifuge for separating the filtered overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream; and

25 a modulator for combining the fourth overflow stream with the first overflow stream, wherein the first overflow stream, the fourth overflow stream or a combination thereof is suitable for use by an upgrader.

30 The apparatus may further include a second cyclone upstream of the first centrifuge for separating the second underflow stream into a fifth overflow stream and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream, wherein the second overflow stream, the fifth overflow stream or a combination thereof is separated by the first centrifuge.

-3tt-

The apparatus may further include a treater for treating the bitumen feed with a solvent upstream of the inclined plate separator.

5 **BRIEF DESCRIPTION OF THE DRAWINGS**

In the accompanying drawings which illustrate embodiments of the invention,

FIG. 1 illustrates a treatment system for concentrating hydrocarbons in a bitumen-rich froth feed according to a first embodiment of the present invention;

-4-

FIG. 2 illustrates a treatment system for concentrating hydrocarbons in a bitumen-rich froth feed according to another embodiment of the present invention;

FIG. 3 illustrates a treatment system for concentrating hydrocarbons in a bitumen-rich froth feed according to another embodiment of the present invention;

5 FIG. 4 illustrates a treatment system for concentrating hydrocarbons in a bitumen-rich froth feed according to another embodiment of the present invention;

FIG. 5 illustrates a treatment system for concentrating hydrocarbons in a bitumen-rich froth feed according to another embodiment of the present invention;

10 FIG. 6 illustrates a treatment system for concentrating hydrocarbons in a bitumen-rich froth feed according to another embodiment of the present invention;

FIG. 7 illustrates a treatment system for concentrating hydrocarbons in a bitumen-rich froth feed according to yet another embodiment of the present invention;

15 FIG. 8 illustrates a treatment system for concentrating hydrocarbons in a bitumen-rich froth feed according to yet another embodiment of the present invention;
and

FIG. 9 illustrates a treatment system for concentrating hydrocarbons in a bitumen-rich froth feed according to yet another embodiment of the present invention.

DETAILED DESCRIPTION

20 Reference will now be made in detail to implementations and embodiments of various aspects and variations to the present invention, examples of which are illustrated in the accompanying drawings.

Referring to FIG. 1, there is shown a first embodiment of a system **10** adapted for concentrating hydrocarbons in a bitumen feed in accordance with one aspect of the present invention. The system **10** comprises a plurality of separation stages (including at least stages **I**, **II**, **III**), each having at least one separation unit to assist in the staged
25 concentration of hydrocarbons in the bitumen feed. As illustrated in the first

-5-

embodiment, in one aspect of the present invention, the separation units comprise an inclined plate separator **20** at separation stage **I**, a first hydrocarbon cyclone **30** at separation stage **II**, a set of filters **38** at separation stage **III** and a first centrifuge **40** at separation stage **IV**, which are operably configured to provide the system **10** for concentrating hydrocarbons in a bitumen feed stream **70**. For the purposes of this specification, hydrocarbon cyclones are also referred to as “hydrocyclones” or simply as cyclones.

As illustrated in FIG. **1**, a bitumen feed source **12** provides the source of bitumen enriched feed which is supplied to a conduit or line **11** as a bitumen feed stream **70**. The bitumen feed source **12** may be a storage tank or facility, a primary separation vessel or another treatment system upstream of the system **10**. The bitumen feed stream **70** serves as an input stream to the system **10** and is fed through line **11** to the inclined plate separator **20** for processing. In the first embodiment, the bitumen feed stream **70** is a bitumen froth stream that will typically have the consistency of deaerated froth. In this specification, the term “bitumen froth” means a mixture of air, water, bitumen and solids, which is typically formed upstream of the system **10** using an oil sands primary separation vessel or another separation unit upstream of the system **10** to initially produce a bitumen-enriched froth.

The bitumen feed stream **70** will typically have a varying degree of constituent components (bitumen, water and solids) due to, for instance, variations in the oil sands composition processed upstream of the system **10**. Typically, the bitumen feed stream **70** comprises from about 45 to 65 wt. % bitumen, from about 8 to 15 wt. % solids and from about 25 to 50 wt. % water.

In the first embodiment, a solvent **14** comprising a liquid hydrocarbon is added to the bitumen feed stream **70** to reduce its hydrocarbon density and its viscosity. Preferably, the addition of the solvent **14** also helps solvate the hydrocarbons from solids in the bitumen feed stream **70** and from organic films surrounding water droplets in the bitumen feed stream **70**. The solvent **14** may be any solvent capable of diluting the bitumen feed stream **70** so as to reduce the hydrocarbon density and the viscosity of the bitumen feed stream **70**. In the first embodiment, the solvent **14** may comprise naphtha.

-6-

Alternatively, other solvents may be used including, for example, paraffinic or alkane hydrocarbon solvents. In this specification, the solvent **14** is also referred to as a diluent. The solvent **14** is preferably miscible with the hydrocarbon components of the bitumen feed stream **70**, and preferably can be readily recovered from the hydrocarbon components of the bitumen feed stream **70**.

The solvent **14** can be added at one or more addition points within or in advance of the system **10**. In the first embodiment, the solvent **14** is added in advance of introducing the bitumen feed stream **70** to the inclined plate separator **20** in separation stage **I**. In the alternative, the solvent **14** may be added to or mixed with one or more other streams of the system **10** in addition to or instead of the bitumen feed stream **70**. In this specification the term “hydrocarbons” refers to the hydrocarbons found in the bitumen, the solvent **14** (diluent) or both.

The diluted bitumen feed stream **70** is fed through line **11** to the inclined plate separator **20**. The inclined plate separator **20** is a conventional inclined plate separator which processes an incoming bitumen feed stream so as to produce a bitumen-enriched product stream comprising a bitumen concentration suitable for processing by an upgrader **24**, and a residual bitumen-lean stream (also referred to as a reject stream) comprising a concentration of bitumen lower than that in the product stream. Inclined plate separators are well known in the art. For illustration purposes only, inclined plate separators that may be used in system **10** include inclined plate separators available from Krebs Engineers (www.krebs.com) or from Parkson Industrial Equipment Company of Florida, U.S.A.

As illustrated in FIG. **1**, the inclined plate separator **20** separates the incoming diluted bitumen feed stream **70** into a first overflow stream **74** and a first underflow stream **76**. The first overflow stream **74** is a bitumen-enriched product stream. Preferably, at least about 60 wt. % of the bitumen found in the bitumen feed stream **70** will be concentrated in the bitumen-enriched product stream formed by the first overflow stream **74**. More preferably at least about 70 wt. % of the bitumen found in the bitumen feed stream **70** will be concentrated in the first overflow stream **74**.

-7-

The first overflow stream **74** typically comprises from about 55 wt. % to about 65 wt. % bitumen; from about 30 wt. % to about 40 wt. % diluent; from about 0.5 wt. % to about 2.0 wt. % solids; and from about 1.0 wt. % to about 6.0 wt. % water. Preferably, the first overflow stream **74** in FIG. **1** has a D/B ratio (diluent to bitumen weight ratio) of about 0.45 to about 0.62. The first overflow stream **74** also preferably comprises a hydrocarbon content of about 93 wt. % to about 98 wt. %.

The first overflow stream **74** is fed to line **13**, and may be sent directly to the upgrader **24**. Alternatively, the first overflow stream **74** may be directed to a storage unit. In another aspect, the first overflow stream **74** may be further processed before being supplied to the upgrader **24**.

Although the first underflow stream **76** comprises a hydrocarbon concentration which is significantly lower than that of the first overflow stream **74**, the first underflow stream **76** typically will still contain bitumen that will be desirable to recover for processing by the upgrader **24**. Therefore, the first underflow stream **76** is fed through line **15** to separation stage **II** for further treatment within the system **10**.

As shown in FIG. **1**, the first underflow stream **76** is fed to a first hydrocyclone **30** in separation stage **II**. The first hydrocyclone **30** provides an intermediate mechanism within the system **10** for processing the first underflow stream **76** in order to concentrate a further hydrocarbon component (bitumen and diluent) by separating out a portion of water and solids from the first underflow stream **76**. Hydrocyclones are well known by persons skilled in the art. In the first embodiment, for illustration purposes, the first hydrocyclone **30** is of the type shown in FIG. **2** of Canadian Patent No. 2,400,258. However, in other alternatives, other conventional hydrocyclones may be used. For example, other suitable hydrocyclones include those manufactured by Krebs Engineers (www.krebs.com).

The first hydrocyclone **30** separates the first underflow stream **76** into a second overflow stream **78** and a second underflow stream **80**. The second overflow stream **78** has a significantly higher hydrocarbon concentration (bitumen and diluent) than that of the second underflow stream **80**. In addition, the second overflow stream **78** will have

significantly lower solids and water contents than those of the second underflow stream **80**.

The second overflow stream **78** is an intermediate stream comprising a hydrocarbon concentration which is lower than the hydrocarbon concentration of the first overflow stream **74**. However, the second overflow stream **78** typically will still contain hydrocarbons that are desirable to recover as part of the final product stream that may be used by an upgrader. One of the challenges with concentrating hydrocarbons from this intermediate stream (second overflow stream **78**) is the desire to efficiently produce a secondary product stream that comprises concentrated hydrocarbons (bitumen and diluent) from the intermediate stream (second overflow stream **78**) while maintaining a quality of the secondary product stream suitable for further processing in the upgrader **24**. In this regard, having a secondary product stream, produced by the system **10** from the processing (treatment) of the second overflow stream **78**, comprising less than about 4.0 wt. % solids and less than about 6.0 wt. % water has been found to be of suitable quality for use by the upgrader **24**. However, having a secondary product stream comprising even lower solids and water contents is much more preferred in order to enhance hydrocarbon concentration, improve the performance of the upgrader **24**, and reduce its maintenance requirements. Preferably, the product stream to be fed to the upgrader **24** (overflow stream **74** or the secondary product stream) comprises less than about 2.0 wt. % solids, more preferably comprises less than about 1.4 wt. % solids, more preferably comprises less than about 1.2 wt. % solids and more preferably yet comprises less than about 1.1 wt. % solids and even more preferably yet comprises less than 0.5 wt. % solids. Preferably, the product stream to be fed to the upgrader **24** also comprises less than about 3.0 wt. % water, more preferably comprises less than about 1.5 wt. % water, and more preferably yet comprises about or less than about 1.0 wt. % water. It has been found that keeping the water content at about 1.5 wt. % or less in the product stream (overflow stream **74** or the secondary product stream) to be fed to the upgrader **24** is particularly preferably as this contributes to a substantial decrease in the number of erosion/corrosion events seen in the upgrader **24** due to chlorides, which advantageously results in much less wear on the upgrader equipment, significantly fewer maintenance

-9-

requirements, and significantly less degradation in the operation of the upgrader and fewer undesirable interruptions in operations.

The second overflow stream **78** is preferably fed via line **17** to a filtration-based separation stage **III** comprising one or more filters **38**, such as Cunos™ filters, which are used to filter out a portion of the solids (including tramp or trash material) in the second overflow stream **78**. The filtration of the second overflow stream **78** by filters **38** results in filtered stream **79**, which is fed through line **17A** to separation stage **IV**.

Separation stage **IV**, comprising first centrifuge **40**, forms part of the system **10** in order to further improve the quality of the secondary product stream that will be produced and eventually be available for processing by the upgrader **24**. In this regard, the addition of first centrifuge **40** within the system **10** provides a mechanism for further enhancing the concentration of hydrocarbons (bitumen and diluent) from the second overflow stream **78** and for reducing the quantity of contaminants (e.g. solids and water) in the secondary product stream that is produced for eventual use by the upgrader **24**.

It has been found that keeping the solids content (coarse and fine solids) at about 1.0 wt. % or less in the product stream to be fed to the upgrader **24** is particularly preferably as this contributes to a substantial decrease in the number of erosion events seen in the upgrader **24**, which advantageously results in much less wear on the upgrader equipment, significantly fewer maintenance requirements, and significantly less degradation in the operation of the upgrader and fewer undesirable interruptions in operations. Achieving a product stream comprising about or less than about 1.0 wt. % solids from the processing of an intermediate stream such as second overflow stream **78** can be challenging due to the high mineral content in the second overflow stream **78** resulting from the separation techniques applied by the inclined plate separator **20** and the first hydrocyclone **30**. The introduction of the first centrifuge **40** to the system **10** and the processing of second overflow stream **78** by the first centrifuge **40**, preferably after filtration through filters **38**, advantageously assists significantly in keeping the solids content in the secondary product stream **82** at about 1.0 wt. % or less during the extended and continuing operation of the system **10**. In addition, feeding the second overflow stream **78** to the first centrifuge **40** rather than to or upstream of the inclined

-10-

plate separator **20** avoids placing additional circulating load on the inclined plate separator **20** and avoids raising the solids and water content of the first overflow stream **74** and the first underflow stream **76** that would result from re-introducing to the inclined plate separator **20** additional solids-rich material downstream of the inclined plate separator **20**.

In FIG. 1, the second overflow stream **78** is fed through line **17**, filters **38** and line **17A** to the first centrifuge **40**. The first centrifuge **40** separates out a portion of the remaining fine solids (i.e., minerals or other particulates such as clays having particle sizes of less than about 44 microns) dispersed in water from the second overflow stream **78** to produce a third overflow stream **82** (i.e. the secondary product stream in FIG. 1) and a third underflow stream **84**, with the third underflow stream **84** comprising the removed portion of the remaining fine solids and water. Preferably, the first centrifuge **40** is capable of removing a significant portion of fine solids from the second overflow stream **78** so that the third overflow stream **82** comprises a lower fine solids content than the fine solids content of the second overflow stream **78**. More preferably, the third overflow stream **82** comprises a significantly lower fine solids content than that of the second overflow stream **78**. In the first embodiment, the first centrifuge **40** is a disk centrifuge produced by Westfalia, although other centrifuges capable of removing a significant portion of fine solids from a feed stream may also be used.

The introduction of the first centrifuge **40** at separation stage **III** and the feeding of at least the second overflow stream **78** to the first centrifuge **40**, preferably via filters **38**, advantageously provides a configuration that not only can produce a secondary product stream (third overflow stream **82**) that has about 1.0 wt % solids content or less, but in which the solids content can typically be maintained over continued operation at about 0.4 wt. % to about 0.8 wt. %. In addition, the third overflow stream **82** will have a significantly higher hydrocarbon concentration (bitumen and diluent) than that of the third underflow stream **84**, and will have significantly lower solids and water contents than those of the third underflow stream **84**. The third overflow stream **82** typically comprises from about 54 wt. % to about 60 wt. % bitumen; from about 33 wt. % to about 39 wt. % diluent; from about 0.4 wt. % to about 0.8 wt. % solids; and from about 5.0 wt. % to about 12.0 wt. % water. In addition, the third overflow stream **82** typically

-11-

has a D/B weight ratio of about 0.6 to about 0.7 and comprises a hydrocarbon content of about 88 wt. % to about 95.5 wt. %.

The third overflow stream **82** produced in the system **10** will preferably have a sufficiently high concentration of hydrocarbons (bitumen and diluent) and a sufficiently low concentration of contaminants (e.g. solids and water) such that the third overflow stream **82** is of a quality suitable to be used by the upgrader **24**. In the first embodiment, the third overflow stream **82** is fed through line **21** and combined with the first overflow stream **74** in line **13** to produce a combined product stream **100** for use by the upgrader **24**.

In the first embodiment, the second underflow stream **80** and the third underflow stream **84** are reject streams, which may be combined and fed to a solvent recovery unit **36** in order to recover the residual solvent **14** (diluent) for reuse within the system **10** before the combined reject stream (**80** and **84**) is sent to a tailings pond (not shown).

In one aspect of the present invention, the staged system **10** shown in FIG. **1** or any of the systems shown in the other figures that follow provide for a higher gravitational G-force in the gravitational-based separation applied to produce product streams having concentrated substantially all of the hydrocarbons initially present in the input bitumen feed stream **70**. In this aspect, the system **10** in FIG. **1** for example comprises separation stages wherein the gravitational separation forces applied by the first hydrocyclone **30** are at least significantly higher than those applied by the inclined plate separator **20**, and the gravitational separation forces applied by the first centrifuge **40** are substantially higher than those applied by the first hydrocyclone **30**. In this regard, the inclined plate separator **20** has a gravitational separation force of about 1 G; the first hydrocyclone **30** typically has a gravitational separation force of about 200 to about 700 Gs, and the first centrifuge **40** has a gravitational separation force greater than that of the first hydrocyclone **30**, preferably at least about 800 Gs.

Although not shown in FIG. **1** or the other figures that follow, it will be understood that ancillary elements and machinery such as pumps, intermediate valves and the like will be used for proper operation of the embodiments shown. These ancillary elements will be well understood to those skilled in the art. In addition, although separation stages in

-12-

FIG. 1 or in the figures that follow are shown, for illustration purposes, as using a single separation unit in each stage, multiple separation units can be used in each separation stage of the first embodiment (e.g. multiple inclined plate separators in stage **I**, multiple hydrocyclones in stage **II** or multiple centrifuges in stage **IV**), and in other embodiments depending upon the operational scale of the facility implementing one or more of the aspects of the present invention.

In addition to the various aspects and features discussed above, the system **10** and the process applied thereto can have a variety of aspects and features to further enhance operations. Furthermore, as with the aspects and features described above, each of the following aspects and features individually provides a beneficial enhancement and is an embodiment of the present invention. These additional aspects and features will now be described below.

Referring to FIG. 2, there is shown another embodiment (system **10A**) in which, in another aspect of the present invention, a second hydrocyclone **32** is included in a variation of the system **10** shown in FIG. 1. In the embodiment shown in FIG. 2, the second underflow stream **80** from the first hydrocyclone **30** in separation stage **II** is fed as an input stream to the second hydrocyclone **32** in separation stage **V** through line **19**. The second hydrocyclone **32** forms a further separation stage, in which the second underflow stream **80** is processed to concentrate a portion of the residual hydrocarbons (bitumen and diluent) remaining in the second underflow stream **80**. As shown in FIG. 2, the second underflow stream **80** is separated by the second hydrocyclone **32** into a fourth overflow stream **86** and a fourth underflow stream **88**. The fourth overflow stream **86** will have a hydrocarbon concentration (bitumen and diluent) higher than that of the fourth underflow stream **88**. In addition, the fourth overflow stream **86** will have lower solids and water contents than those of the fourth underflow stream **88**. The fourth underflow stream **88** is treated as a reject stream which is fed through line **27**, and eventually supplied to the solvent recovery unit **36** to recover residual solvent **14** for reuse.

The fourth overflow stream **86** is fed through line **25**, and is combined (blended) with the second overflow stream **78** in line **17** to form a combined stream, which preferably is fed

-13-

to filters **38** to filter out a portion of the solids in the combined stream. The filtration of the combined stream formed by second overflow stream **78** and fourth overflow stream **86** by filters **38** results in filtered stream **79A**, which is fed through line **17A** to the first centrifuge **40** for processing as described in connection with the first embodiment shown in FIG. 1. The first centrifuge **40** separates the incoming filtered stream **79A** into an overflow stream **82A** and an underflow stream **84A**. The overflow stream **82A** that is produced preferably contains a sufficiently high hydrocarbon concentration and a sufficiently low solids and water content that the overflow stream **82A** is of a quality suitable for use by upgrader **24**. Optionally, the overflow stream **82A** may be fed to a storage tank **22**. The underflow stream **84A** is a reject stream, which is fed to the solvent recovery unit **36** to recover residual solvent **14** for reuse within the system **10A**.

Referring to FIG. 3, there is shown another embodiment (system **10B**) in which, in another aspect of the present invention, a third hydrocyclone **34** is included in a variation of the system **10A** shown in FIG. 2. In the embodiment shown in FIG. 3, a bitumen feed source **12A** comprising an inter-stage storage tank is used to hold an inventory of deaerated bitumen froth for the system **10B**. The inter-stage storage tank has a conical bottom in order to minimize the amount of particulate build-up that can arise at the bottom of the tank and in order to assist in maintaining the consistency of the deaerated bitumen froth. Preferably, the deaerated bitumen froth from the inter-stage storage tank (**12A**) is fed to a grinder **9**, such as a Macho Muncher™ available from JWC Environmental of Costa Mesa, California. The deaerated bitumen froth that serves as a feed source may contain various organic materials, such as pieces of roots, branches, coal, other carbonaceous material and the like, which may obstruct or plug up over time the system **10B**. In the embodiment shown in FIG. 3, such organic materials are reduced in size before the deaerated bitumen froth is processed by the various separation stages.

The grinder **9** grinds pieces of roots, branches, coal and other organic materials to a size small enough not to plug pumps or separation units within the system **10B**, preferably down to about ¼ inch in diameter or less. By grinding down pieces of material in the deaerated bitumen froth that could obstruct parts of the system **10B**, the deaerated bitumen froth can be fed to the separation units while avoiding bitumen recovery losses

-14-

that would arise from the pre-treatment removal of such obstructions. The bitumen feed **70** (deaerated bitumen froth) is then fed through line **11** for further processing in the manner described in the above embodiments (systems **10** and **10A**). Alternatively, grinder **9** may be situated to process diluted bitumen streams. For instance, the grinder **9** may be situated to process bitumen feed stream **70** after solvent **14** is added or to process first underflow stream **76**.

As shown in FIG. 3, the system **10B** includes three hydrocyclone separation stages **II**, **V** and **VI** which respectively comprise hydrocyclones **30**, **32** and **34**. The hydrocyclones **30**, **32** and **34** in separation stages **II**, **V** and **VI** form an intermediate counter-current circuit within the system **10B** and serve to recondition or “wash” the first underflow stream **76** produced by the inclined plate separator **20**. With the system **10B**, additional hydrocarbons that would not otherwise be recovered in the second overflow stream **78** obtained from the initial processing by the first hydrocyclone **30** (in the first embodiment shown in FIG. 1) of the first underflow stream **76** are concentrated in the fourth overflow stream **86** produced by the second hydrocyclone **32**, and reintroduced via line **25** into the first underflow stream **76** in line **15** for further processing by the first hydrocyclone **30**. Similarly, yet additional hydrocarbons that were not concentrated in the fourth overflow stream **86** from the processing of the second underflow stream **80** by the second hydrocyclone **32** are concentrated from the fourth underflow stream **88** by the third hydrocyclone **34** in separation stage **VI**, and reintroduced via line **29A** as part of further overflow stream **87** to line **19** for further processing by the second hydrocyclone **32** in separation stage **V**. The introduction of the intermediate counter-current circuit in system **10B** provides for an enhanced concentration of hydrocarbons in the second overflow stream **78**, and can improve operational efficiency and power requirements.

In the embodiment shown in FIG. 3, the second overflow stream **78** in line **17** is preferably fed to filters **38** to filter out a portion of the solids (including tramp or trash material) which results in a filtered stream **79B** that is fed through line **17A** to the first centrifuge **40** for processing as described in connection with the embodiment shown in FIG. 1. The first centrifuge **40** separates the filtered stream **79B** into an overflow stream **82B** and an underflow stream **84B**.

-15-

The overflow stream **82B** will have a higher hydrocarbon concentration (bitumen and diluent) than that of the underflow stream **84B**, and will have a significantly higher bitumen concentration than that of the underflow stream **84B**. The overflow stream **82B** will also have significantly lower solids and water contents than those of the underflow stream **84B**. As compared to the first embodiment in FIG. 1, the overflow stream **82B** will also have a higher hydrocarbon concentration and a higher bitumen concentration than those of the overflow stream **82**.

It will be noted that the intermediate three-stage counter-current circuit shown in FIG. 3 is illustrative, and that in other variations, other intermediate multi-stage counter-current circuits could be used. For example, in another variation, the system **10B** may comprise separation stages **II** and **V**, but no separation stage **VI**, with the underflow stream **88** of the second hydrocyclone **32** being fed to the underflow stream **84B** in line **23A** rather than being processed through a further processing cycle.

Referring to FIG. 4, there is shown a variation of the system **10A** illustrated in FIG. 2. In FIG. 4, the system **10C** includes the optional addition of a chemical additive **16**, such as a demulsifier or surfactant, to promote or enhance phase separation. As also illustrated in FIG. 4, preferably solvent **14**, in the form of a diluent, is introduced to the bitumen feed stream **70** resulting in diluted feed stream **72**. Diluted feed stream **72** typically comprises from about 32 wt. % to about 43 wt. % bitumen; from about 14 wt. % to about 24 wt. % diluent; from about 7 wt. % to about 12 wt. % solids; and from about 30 wt. % to about 40 wt. % water. Preferably, the diluted feed stream **72** in FIG. 4 has a D/B weight ratio of about 0.43 to about 0.55.

In the embodiment shown in FIG. 4, the chemical additive **16** is introduced into the diluted bitumen feed stream **72** in line **11**. The chemical additive **16** may be introduced into the diluted bitumen feed stream **72** in any suitable way, for example with a quill (not shown). For illustration purposes, the chemical additive that is introduced is Emulsotron™ 141 available from Champion Technologies (www.champ-tech.com) of Houston, Texas and is injected into the feed stream **72** at about 20 to about 60 ppm. Dosing of the chemical additive can vary with performance objectives. In addition, other chemical additives may have other dosage rates to achieve a similar effect. In the

-16-

embodiment shown in FIG. 4, the addition of the chemical additive **16** can with the efficacy of concentrating the hydrocarbons in the first overflow stream **74**, the second overflow stream **78**, the fourth overflow stream **86**, and the third overflow stream **82C**, and, in turn, can result in the product stream **102C** having an improved hydrocarbon concentration compared to a product stream produced without the use of the chemical additive **16**.

Advantageously, in the system **10C**, the introduction of the chemical additive **16** further enhances the quality of the product streams produced. In this regard, the first overflow stream **74** in FIG. 4 is a bitumen-enriched product stream that typically comprises from about 63 wt. % to about 69 wt. % bitumen; from about 30 wt. % to about 35 wt. % diluent; from about 0.3 wt. % to about 0.55 wt. % solids; and from about 0.9 wt. % to about 1.5 wt. % water. Preferably, the first overflow stream **74** in FIG. 4 has a D/B weight ratio of about 0.43 to about 0.55. The first overflow stream **74** also comprises a hydrocarbon content of about 98.1 wt. % to about 98.7 wt. %. In addition, the third overflow stream **82C** typically comprises from about 55 wt. % to about 60 wt. % bitumen; from about 35.0 wt. % to about 40.0 wt. % diluent; from about 0.3 wt. % to about 0.6 wt. % solids; and from about 1.7 wt. % to about 4.1 wt. % water. In addition, the third overflow stream **82C** typically has a D/B ratio of about 0.58 to about 0.69 and comprises a hydrocarbon content of about 95 wt. % to about 98 wt. %.

In another aspect of the present invention, the chemical additive **16** may be additionally or alternatively introduced at other addition points within the applicable system (e.g. system **10C**). For example, in variations of the embodiment shown in FIG. 4, the chemical additive **16** may be added to one or more of the first overflow stream **74**, the first underflow stream **76**, the second overflow stream **78**, the second underflow stream **80**, or the fourth overflow stream **86**.

In system **10C**, the third overflow stream **82C** will preferably be of a quality suitable to be combined with the first overflow stream **74** to form a product stream **102C** for use in the upgrader **24**. Alternatively, the product stream **102C** may be introduced into a further separation stage comprising a storage tank. The fourth underflow stream **88** and the

-17-

third underflow stream **84C** may be combined in line **23A** and fed to the solvent recovery unit **36** to recover the solvent **14**.

Referring to FIG. 5, there is shown system **10D**, which is another variation of the system **10A** shown in FIG. 2. In the embodiment shown in FIG. 5, the system **10D** comprises a further separation stage comprising a settling tank **23**. The system **10D** also may optionally include the addition of the chemical additive **16** in the manner described for system **10C** shown in FIG. 4 or, alternatively, another chemical additive to enhance separation within the settling tank **23**. In the system **10D**, storage tank **22** serves as an initial settling facility in which a residual layer at about or near the bottom of the storage tank **22** is fed as a residual stream through line **39** to the settling tank **23**. The residual stream will still contain residual hydrocarbons that are desirable to concentrate. The residual stream collects in the settling tank **23** as a deposit in which hydrocarbon-based components in an aqueous phase are allowed to settle to or near the bottom of the settling tank **23**. The layers settling about or near the top of the storage tank **22** and the settling tank **23** are preferably of a quality suitable to be introduced into the upgrader **24**, and may be fed to the upgrader **24**. In an alternative embodiment of the system **10D**, an upper layer in the settling tank **23** may also be re-introduced into the storage tank **22**.

The hydrocarbon-based components (residual bitumen and diluent) that are present in the aqueous phase which settles in the settling tank **23** form a slops-type mixture comprising bitumen, diluent (solvent), fine solids and water, which can be routed to solvent recovery unit **36** to recovery a portion of the diluent before the remaining mixture is directed to a tailings pond. However, this approach results in a significant loss of diluent and bitumen. Preferably, at least a portion of the diluent and bitumen would be recovered from the slops-type mixture that is collected, such as in the settling tank **23**.

In general, the slops-type mixture may be produced from the processing of a stream within the applicable system (e.g. system **10D**) downstream of the centrifuge **40** or one of the hydrocyclones (**30**, **32**). As illustrated in FIG. 5, at least a portion of the slops-type mixture in settling tank **23** is preferably recycled or reintroduced back into system **10D** at one or more locations in order to further improve the recovery of bitumen and

-18-

diluent (solvent). In the variation shown in FIG. 5, a portion of the slops-type mixture is pumped as a residual stream **96** through line **41** and fed to line **11** where it is combined with diluted bitumen feed stream **72** for reintroduction to and further processing through the system **10D** preferably beginning with the inclined plate separator **20** to obtain a further hydrocarbon concentration. Optionally or in addition, the residual stream **96** may be fed through line **45** so as to be combined with the second overflow stream **78** in the middle of the system **10D** or another location such as with the first underflow **76** (as illustrated in FIG. 8 and 9). Since the slops-type mixture forms a fairly tight emulsion in settling tank **23**, blending this mixture with less emulsified material upstream within system **10D** as discussed above contributes to the enhanced recovery of bitumen and diluent from the mixture.

The overflow stream **82D** that is produced in system **10D** preferably contains a sufficiently high hydrocarbon concentration and sufficiently low water and solids contents such that it is of a quality suitable for combining with the first overflow stream **74** to form a product stream **102D**. As with the earlier embodiments described above, the underflow stream **84D** is a reject stream, which is fed to the solvent recovery unit **36** to recover residual solvent **14** for reuse.

Referring to FIG. 6, there is shown another embodiment (system **10E**), which is a variation of the system **10D** shown in FIG. 5. In the embodiment shown in FIG. 6, the second overflow stream **78** formed in separation stage **II** by the first hydrocyclone **30** is reintroduced through line **17** back into the bitumen feed stream **70** for further processing in the inclined plate separator **20**. The reintroduction of the second overflow stream **78** to the bitumen feed stream **70** forms a combined feed stream **72**.

The first underflow stream **76** is processed by the hydrocyclone **30** as described in the previous embodiments (e.g. as in system **10A**), producing the second overflow stream **78** and the second underflow stream **80**. The second underflow stream **80** is fed through line **19** to the second hydrocyclone **32**, where it is separated into the fourth overflow stream **86** and the fourth underflow stream **88**.

In this embodiment, the fourth overflow stream **86** serves as an intermediate feed stream that is preferably fed through line **25** into filters **38**. Filters **38** process the fourth

-19-

overflow stream **86** to filter out a portion of the solids, resulting in a filtered stream **79E**, which is fed through line **21** for processing by the first centrifuge **40** as was described in connection with the first embodiment shown in FIG. **1**. The first centrifuge **40** separates the incoming the filtered stream **79E** into an overflow stream **82E** and an underflow stream **84E**.

In system **10E**, the overflow stream **82E** obtained from the first centrifuge **40** is fed through line **21** to a storage tank **22A**. The storage tank **22A** is separate from the storage tank **22**. The underflow stream **84E** is a reject stream, which is fed through line **23A** to the solvent recovery unit **36** to recover the residual solvent **14** for reuse. In the system **10E**, the two storage tanks **22** and **22A** serve as separate initial settling facilities for the first overflow stream **74** and the overflow stream **82E** respectively.

The first overflow stream **74** and the overflow stream **82E** which accumulate in the storage tanks **22** and **22A** respectively will typically each separate into a hydrocarbon-rich layer and a residual layer, with the hydrocarbon-rich layer having a hydrocarbon concentration significantly higher than that of the residual layer. The preferred hydrocarbon-rich layers which typically collect at about or near the top of the storage tanks **22** and **22A** may be fed to the upgrader **24** for processing.

Residual layers which collect at about or near the bottom of the storage tanks **22** and **22A** are preferably fed as residual streams a further separation stage comprising the settling tank **23**. The residual streams entering the settling tank **23** still contain residual hydrocarbons that are desirable to concentrate. The residual streams further separate in the settling tank **23** into a hydrocarbon-rich layer near the top of the tank and an aqueous layer near the bottom of the tank, which will still comprise some residual hydrocarbons. The hydrocarbon-rich layer can be fed from the settling tank **23** to the upgrader **24**. Alternatively, the hydrocarbon-rich layer in the settling tank **23** may be fed back into the storage tank **22** to enhance the separation in the settling tank **22**. The aqueous layer in the settling tank **23** comprising residual hydrocarbons may be pumped as stream **96** through line **41**. In system **10E**, the stream **96** is fed to line **11** where it is combined with the diluted bitumen feed stream **70** and with the second overflow stream **78** for re-processing by the system **10E**, beginning with the inclined plate separator **20**.

-20-

Optionally, the stream **96** may also be fed through line **45** so as to be combined with the fourth overflow stream **86** prior to being further processed by filters **38** and the first centrifuge **40**. In another variation, the stream **96** may be combined with the first underflow stream **76** prior to being further processed by the first hydrocyclone in separation stage **II**. The system **10E** also may include the addition of a chemical additive in the manner described for system **10C** (FIG. 4) or system **10D** (FIG. 5).

Referring to FIG. 7, there is shown another embodiment (system **10F**), which is a variation of the system **10E** shown in FIG. 6. In the embodiment shown in FIG. 7, the fourth overflow stream **86** formed in separation stage **IV** by the second hydrocyclone **32** is introduced through line **25** back into the bitumen feed stream **70**. Similarly to what was previously described in connection with the embodiment in FIG. 6, the introduction of the fourth overflow stream **86** into the bitumen feed stream **70** in the system **10F** produces a combined feed stream prior to processing of the bitumen feed stream **70** in the inclined plate separator **20**.

In this embodiment, the second overflow stream **78** obtained from the first hydrocyclone **30** in separation stage **II** is fed through line **17** preferably into filters **38**, resulting in a filtered stream **79F**, which is fed through line **17A** to the first centrifuge **40** for processing as described in connection with the first embodiment shown in FIG. 1. The first centrifuge **40** separates the filtered stream **79F** into an overflow stream **82F** and an underflow stream **84F**. The system **10F** also may include the addition of a chemical additive in the manner described for system **10C** (FIG. 4) or system **10D** (FIG. 5).

Referring to FIG. 8, in another embodiment there is shown system **10G** which is a variation of the embodiment shown in FIG. 5. In this embodiment, the second overflow stream **78** and the fourth overflow stream **86** are combined into a hydrocarbon-rich stream that is fed to one or more scroll centrifuges **42**. The scroll centrifuges **42** are introduced into system **10G** to separate coarser particulate matter (e.g. sands, coal, remaining wood pieces and the like) from the incoming hydrocarbon-rich stream. The scroll centrifuges **42** separate the incoming hydrocarbon-rich stream into overflow stream **82G** and underflow stream **84G**. The overflow stream **82G** comprises a higher concentration of hydrocarbons (bitumen and diluent) than that of the underflow

-21-

stream **84G** and also comprises a higher concentration of bitumen than that of the underflow stream **84G**. The overflow stream **82G** also comprises a lower solids content than the underflow stream **84G**.

5 Optionally, the second overflow stream **78** and the fourth overflow stream **86** may be combined with a portion of the bitumen feed **70**, which is fed through line **11A**. The addition of a portion of the bitumen feed stream **70** to overflow stream **78** can assist in further improving the concentration of hydrocarbons in the overflow stream **82G**.

10 The overflow stream **82G** is fed through line **21** into filters **38** which process the overflow stream **82G** to remove a portion of the solids, resulting in a filtered stream **90**. Filtered stream **90** is fed through line **21** for processing by centrifuge **40** as was described in connection with the first embodiment shown in FIG. 1. Centrifuge **40** processes the filtered stream **90** to produce overflow stream **92** and underflow stream **94**. The product overflow stream **92** serves as a product stream having a quality suitable for use in the upgrader **24**.

15 As discussed earlier with reference to the first embodiment shown in FIG. 1, solvent **14** may optionally be added at multiple addition points to the systems contemplated in the specification. For illustration purposes, FIG. 8 shows optional additional points which include the introduction of additional solvent to: (a) first underflow stream **76** in advance of first hydrocyclone **30** (shown as addition point **AP₁**); (b) second underflow stream **80**
20 in advance of second hydrocyclone **32** (shown as addition point **AP₂**); (c) second overflow stream **78** in advance of centrifuge **42** (shown as addition point **AP₃**); and (d) product stream **104** in advance of storage tank **22** (shown as addition point **AP₄**). The introduction of additional solvent at secondary addition points can help assist in hydrocarbon recovery. In addition, introducing additional solvent at one or more
25 secondary addition points (e.g. at **AP₂** or **AP₃**) can also assist in removing middlings materials from the applicable system (e.g. system **10G**). Preferably, additional solvent is added at a rate that does not increase the overall D/B ratio within the applicable system beyond a predetermined threshold. Preferably, the predetermined threshold for the D/B ratio does not exceed 0.75, and in order to improve the management of solvent losses,

-22-

more preferably the predetermined threshold for the D/B ratio does not exceed about 0.65.

Referring to FIG. 9, in yet another aspect there is shown system **10H**, which is a variation of the system **10D** shown in FIG. 5. In the embodiment shown in FIG. 9, filters **38** and centrifuge **40** are removed and the overflow stream **86** produced by hydrocyclone **32** is fed through line **25** to storage tank **22A**. Similar to the approach in system **10D**, storage tank **22A** serves as an initial settling facility in which a residual layer at about or near the bottom of the storage tank **22A** is fed as a residual stream through line **35** to settling tank **23**. The residual stream forms a slops-type mixture in settling tank **23**, which will contain residual bitumen and diluent (solvent) that are desirable to recover. The slops-type mixture in settling tank **23** is preferably reintroduced back into system **10H** at one or more locations in order to further improve the recovery of bitumen and diluent. In the variation shown in FIG. 9, a portion of the slops-type mixture is pumped as a residual stream **96** through line **41** and fed to line **11** where it is combined with diluted bitumen feed stream **72** for reintroduction to and further processing through the system **10H** beginning with the inclined plate separator **20**. Optionally, the residual stream **96** may be fed through line **45A** so as to be combined with the first overflow stream **76** upstream of hydrocyclone **30**.

Although separation stages **I** through **VI** are shown for illustration purposes in FIG. 1 through 9 using a single separation unit in each stage, in another aspect of the present invention multiple separation units can be used in each separation stage depending upon the operational scale of the facility implementing the present invention. For example, in one preferred embodiment of the system shown in FIG. 3, separation stage **I** comprises a plurality of inclined plate separators cooperating in parallel to process bitumen feed stream **70**, separation stage **II** comprises a plurality of hydrocyclones cooperating in parallel to process the first underflow stream **76**, separation stage **IV** comprises a plurality of disk centrifuges cooperating in parallel to process the second overflow stream **78** and the fourth overflow stream **86**, and separation stage **V** comprises a plurality of hydrocyclones cooperating in parallel to process the fourth underflow stream **80**.

-23-

5

10

In the
specification including the claims, numeric ranges are inclusive of the numbers
defining the range. Citation of references herein shall not be construed as an
admission that such references are prior art to the present invention.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A process for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the process comprising:

separating, in an inclined plate separator, the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

separating, in a first cyclone, the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

separating, in a second cyclone, the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

separating, in a first gravity settler, a combination of the third overflow stream with the first overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, wherein the first overflow stream, the third overflow stream, the fourth overflow stream or a combination thereof is suitable for use by an upgrader; and

recycling a first portion of the fourth underflow stream upstream of the inclined plate separator.

2. The process of claim 1 further comprising combining a second portion of the fourth underflow stream with the first underflow stream.

3. The process of claim 1 or 2 further comprising recycling the second overflow stream upstream of the inclined plate separator.

4. The process of any one of claims 1 to 3 further comprising treating the bitumen feed with a solvent, a chemical additive or a combination thereof prior to the separating step in the inclined plate separator.

5. A process for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the process comprising:

separating, in an inclined plate separator, the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

separating, in a first cyclone, the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

separating, in a second cyclone, the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

separating, in a centrifuge, a combination of the second overflow stream with the third overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream;

combining the fourth overflow stream with the first overflow stream, wherein the first overflow stream, the fourth overflow stream or a combination thereof is suitable for use by an upgrader;

separating a portion of the combination of the fourth overflow stream and the first overflow stream, in a gravity settler, into a fifth overflow stream suitable for use by the upgrader and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream; and

recycling a first portion of the fifth underflow stream upstream of the inclined plate separator.

6. The process of claim 5 further comprising filtering the combination of the second overflow stream with the third overflow stream before the separating step in the centrifuge.

7. The process of claim 6 further comprising combining a second portion of the fifth underflow stream with the second overflow stream, or with the combination of the second overflow stream with the third overflow stream before the separating step in the centrifuge, before filtering or a combination thereof.

8. The process of any one of claims 5 to 7 further comprising treating the bitumen feed with a solvent, a chemical additive or a combination thereof prior to the separating step in the inclined plate separator.

9. A process for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the process comprising:

separating, in an inclined plate separator, the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

separating, in a first cyclone, the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

separating, in a second cyclone, the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

separating, in a centrifuge, the third overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, wherein the fourth overflow stream, the first overflow stream or a combination thereof is suitable for use by an upgrader;

separating a combination of a first portion of the fourth overflow stream and the first overflow stream, in a gravity settler, into a fifth overflow stream suitable for use by the upgrader and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream; and

recycling a first portion of the fifth underflow stream upstream of the inclined plate separator.

10. The process of claim 9 further comprising combining a second portion of the fifth underflow stream with the first underflow stream.

11. The process of claim 10 further comprising combining a third portion of the fifth underflow stream with the third overflow stream.

12. The process of claim 11 further comprising filtering the third overflow stream or a combination of the third overflow stream with the third portion of the fifth underflow stream before the separating step in the centrifuge.

13. The process of any one of claims 9 to 12 further comprising recycling the second overflow stream upstream of the inclined plate separator.

14. The process of any one of claims 9 to 13 further comprising treating the bitumen feed with a solvent, a chemical additive or a combination thereof prior to the separating step in the inclined plate separator.

15. A process for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the process comprising:

separating, in an inclined plate separator, the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

separating, in a first cyclone, the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

separating, in a second cyclone, the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

separating, in a centrifuge, the second overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, wherein each of the first overflow stream and the fourth overflow stream is suitable for use by an upgrader;

separating a combination of a first portion of the fourth overflow stream and a first portion of the first overflow stream, in a gravity settler, into a fifth overflow stream suitable for use by the upgrader and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream;

recycling the third overflow stream upstream of the inclined plate separator; and

recycling a first portion of the fifth underflow stream upstream of the inclined plate separator.

16. The process of claim 15 further comprising combining a second portion of the fifth underflow stream with the second overflow stream to form a combined stream.

17. The process of claim 16 further comprising filtering the second overflow stream or the combined stream before the separating step in the centrifuge.

18. The process of any one of claims 15 to 17 further comprising treating the bitumen feed with a solvent, a chemical additive or a combination thereof prior to the separating step in the inclined plate separator.

19. A process for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the process comprising:

separating, in an inclined plate separator, the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

separating, in a first cyclone, the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

separating, in a second cyclone, the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

separating, in a first centrifuge, the second overflow stream and the third overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream;

separating, in a second centrifuge, the fourth overflow stream into a fifth overflow stream and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream;

combining the fifth overflow stream with the first overflow stream, wherein the first overflow stream, the fifth overflow stream or a combination thereof is suitable for use by an upgrader;

separating the combination of the fifth overflow stream and the first overflow stream, in a gravity settler, into a sixth overflow stream suitable for use by the upgrader and a sixth underflow stream, the sixth overflow stream having a bitumen concentration greater than that of the sixth underflow stream; and

recycling a first portion of the sixth underflow stream upstream of the inclined plate separator.

20. The process of claim 19 further comprising filtering the fourth overflow stream before the separating step in the second centrifuge.

21. The process of claim 19 or 20 further comprising combining a second portion of the sixth underflow stream with the second underflow stream before the separating step in the second cyclone.

22. The process of claim 21 further comprising combining a third portion of the sixth underflow stream with the second overflow stream and the third overflow stream before the separating step in the first centrifuge.

23. The process of any one of claims 19 to 22 further comprising treating the bitumen feed with a solvent, a chemical additive or a combination thereof to form a treated bitumen feed prior to the separating step in the inclined plate separator.

24. The process of claim 23 further comprising combining a portion of the treated bitumen feed with the combination of the second overflow stream and the third overflow stream.

25. The process of claim 23 or 24 further comprising combining a second solvent with the first underflow stream.

26. The process of claim 25 further comprising combining a third solvent with the second underflow stream.

27. The process of claim 26 further comprising combining a fourth solvent with the combination of the third portion of the sixth underflow stream with the second overflow stream and the third overflow stream before the separating step in the first centrifuge.

28. The process of claim 27 further comprising combining a fifth solvent with the combination of the fifth overflow stream with the first overflow stream.

29. A process for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the process comprising:

separating, in an inclined plate separator, the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

separating, in a first cyclone, the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

separating, in a second cyclone, the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

combining the second overflow stream with the third overflow stream to form a combined overflow stream; and

separating, in a first centrifuge, the combined overflow stream to produce a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream.

30. The process of claim 29 further comprising combining the fourth overflow stream with the first overflow stream, wherein the first overflow stream, the fourth overflow stream or a combination thereof is suitable for use by an upgrader.

31. The process of claim 29 or 30 further comprising filtering the combined overflow stream before the separating step in the first centrifuge.

32. The process of claim 31 further comprising combining a portion of the bitumen feed with the second overflow stream or the combined overflow stream before the filtering step, the separating step in the first centrifuge or a combination thereof.

33. The process of claim 29 further comprising:

separating, in a second centrifuge, the fourth overflow stream to produce a fifth overflow stream and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream; and

combining the fifth overflow stream with the first overflow stream, wherein the first overflow stream, the fifth overflow stream or a combination thereof is suitable for use by an upgrader.

34. The process of claim 33 further comprising filtering the fourth overflow stream before the separating step in the second centrifuge.

35. The process of claim 33 or 34 wherein the fifth overflow stream has about 1.2 wt. % solids or less.

36. The process of claim 33 or 34 wherein the fifth overflow stream has about 1.0 wt. % solids or less.

37. The process of claim 33 or 34 wherein the fifth overflow stream has about 0.4 wt. % to about 0.8 wt. % solids.

38. The process of claim 33 or 34 wherein the fifth overflow stream has about 0.3 wt. % to about 0.6 wt. % solids.

39. The process of claim 33 or 34 wherein the fifth overflow stream has about 0.5 wt. % solids or less.

40. The process of claim 33 or 34 wherein the bitumen concentration of the fifth overflow stream is about 95 wt. % or more.

41. The process of claim 33 or 34 wherein the bitumen concentration of the fifth overflow stream is about 98 wt. % or more.

42. The process of any one of claims 29 to 41 further comprising treating the bitumen feed with a solvent, a chemical additive or a combination thereof prior to the separating step in the inclined plate separator.

43. A process for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the process comprising:

separating, in an inclined plate separator, the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

separating, in a first cyclone, the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

separating, in a second cyclone, the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream, and combining the third overflow stream with the first underflow stream;

separating, in a third cyclone, the third underflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, and combining the fourth overflow stream with the second underflow stream;

separating, in a centrifuge, the first overflow stream into a fifth overflow stream and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream; and

combining the fifth overflow stream with the first overflow stream, wherein the first overflow stream, the fifth overflow stream or a combination thereof is suitable for use by an upgrader.

44. The process of claim 43 further comprising processing the bitumen feed in a grinder, treating the bitumen feed with a solvent, or a combination thereof prior to the separating step in the inclined plate separator.

45. A process for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the process comprising:

separating, in an inclined plate separator, the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

separating, in a cyclone, the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

filtering the second overflow stream to form a filtered overflow stream;

separating, in a first centrifuge, the filtered overflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream; and

combining the third overflow stream with the first overflow stream, wherein the first overflow stream, the third overflow stream or a combination thereof is suitable for use by an upgrader.

46. The process of claim 45 further comprising separating, in a second centrifuge, the second overflow stream into a fourth overflow stream and a fourth underflow stream prior to the filtering step, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, wherein the fourth overflow stream is filtered in the filtering step.

47. The process of claim 45 or 46 further comprising treating the bitumen feed with a solvent prior to the separating step in the inclined plate separator.

48. The process of any one of claims 45-47 wherein the third overflow stream has about 1.2 wt. % solids or less.

49. The process of any one of claims 45-47 wherein the third overflow stream has about 1.0 wt. % solids or less.

50. The process of any one of claims 45-47 wherein the third overflow stream has about 0.4 wt. % to about 0.8 wt. % solids.

51. The process of any one of claims 45-47 wherein the third overflow stream has about 0.3 wt. % to about 0.6 wt. % solids.

52. The process of any one of claims 45-47 wherein the third overflow stream has about 0.5 wt. % solids or less.

53. The process of any one of claims 45-47 wherein the bitumen concentration of the third overflow stream is about 95 wt. % or more.

54. The process of any one of claims 45-47 wherein the bitumen concentration of the third overflow stream is about 98 wt. % or more.

55. A process for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the process comprising:

separating, in an inclined plate separator, the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

separating, in a first cyclone, the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

separating, in a second cyclone, the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

combining the second overflow stream with the third overflow stream to form a combined overflow stream;

filtering the combined overflow stream to form a filtered overflow stream;

separating, in a first centrifuge, the filtered overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream; and

combining the fourth overflow stream with the first overflow stream, wherein the first overflow stream, the fourth overflow stream or a combination thereof is suitable for use by an upgrader.

56. The process of claim 55 further comprising separating, in a second centrifuge, the combined overflow stream into a fifth overflow stream and a fifth underflow stream prior to the filtering step, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream, wherein the fifth overflow stream is filtered in the filtering step.

57. The process of claim 55 or 56 further comprising treating the bitumen feed with a solvent prior to the separating step in the inclined plate separator.

58. A process for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the process comprising:

separating, in an inclined plate separator, the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

separating, in a cyclone, the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

separating, in a first centrifuge, the second overflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

filtering the third overflow stream to form a filtered overflow stream;

separating, in a second centrifuge, the filtered overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream; and

combining the fourth overflow stream with the first overflow stream, wherein the first overflow stream, the fourth overflow stream or a combination thereof is suitable for use by an upgrader.

59. The process of claim 58 further comprising treating the bitumen feed with a solvent prior to the separating step in the inclined plate separator.

60. The process of any one of claims 4, 8, 14, 18, 23, 25 to 28, 42, 44, 47, 57 or 59 wherein the solvent, the second solvent, the third solvent, the fourth solvent, or the fifth solvent comprises a liquid hydrocarbon.

61. The process of claim 60 wherein the liquid hydrocarbon comprises naphtha.
62. The process of any one of claims 1 to 61 wherein the first overflow stream has about 1.2 wt. % solids or less.
63. The process of any one of claims 1 to 61 wherein the first overflow stream has about 1.0 wt. % solids or less.
64. The process of any one of claims 1 to 61 wherein the first overflow stream has about 0.9 wt. % to about 1.5 wt. % water.
65. The process of any one of claims 1 to 61 wherein the bitumen concentration in the first overflow stream is about 98 wt. % or more.
66. A system for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the system comprising:

first separation means for a low gravitational separation of the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

second separation means for a first high gravitational separation of the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream, the first high gravitational separation having a higher force than the low gravitational separation;

third separation means for a second high gravitational separation of the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow

stream, the second high gravitational separation having a higher force than the low gravitational separation;

fourth separation means for a gravitational separation of a combination of the third overflow stream with the first overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, wherein the first overflow stream, the third overflow stream, the fourth overflow stream or a combination thereof is suitable for use by an upgrader, the gravitational separation of the fourth separation means having a lower force than the low gravitational separation; and

first recycling means for recycling a first portion of the fourth underflow stream upstream of the inclined plate separator.

67. The system of claim 66 further comprising combining means for combining a second portion of the fourth underflow stream with the first underflow stream.

68. The system of claim 66 or 67 further comprising second recycling means for recycling the second overflow stream upstream of the first separation means.

69. The system of any one of claims 66 to 68 further comprising treating means for treating the bitumen feed with a solvent, a chemical additive or a combination thereof upstream of the first separation means.

70. A system for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the system comprising:

first separation means for a low gravitational separation of the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

second separation means for a first high gravitational separation of the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream, the first high gravitational separation having a higher force than the low gravitational separation;

third separation means for a second high gravitational separation of the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream, the second high gravitational separation having a higher force than the low gravitational separation;

fourth separation means for a gravitational separation of a combination of the second overflow stream with the third overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, the gravitational separation of the fourth separation means having a higher force than each of the first and the second high gravitational separations;

combining means for combining the fourth overflow stream with the first overflow stream, wherein the first overflow stream, the fourth overflow stream or a combination thereof is suitable for use by an upgrader;

fifth separation means for a gravitational separation of a portion of the combination of the fourth overflow stream and the first overflow stream into a fifth overflow stream suitable for use by the upgrader and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream, the gravitational separation of the fifth separation means having a lower force than the low gravitational separation; and

recycling means for recycling a first portion of the fifth underflow stream upstream of the first separation means.

71. The system of claim 70 further comprising filtering means for filtering the combination of the second overflow stream with the third overflow stream upstream of the fourth separation means.

72. The system of claim 71 further comprising combining means for combining a second portion of the fifth underflow stream with the second overflow stream, or with the combination of the second overflow stream with the third overflow stream upstream of the fourth separation means, upstream of the filtering means or a combination thereof.

73. The system of any one of claims 70 to 72 further comprising treating means for treating the bitumen feed with a solvent, a chemical additive or a combination thereof upstream of the first separation means.

74. A system for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the system comprising:

first separation means for a low gravitational separation of the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

second separation means for a first high gravitational separation of the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream, the first high gravitational separation having a higher force than the low gravitational separation;

third separation means for a second high gravitational separation of the second underflow stream into a third overflow stream and a third underflow stream, the third

overflow stream having a bitumen concentration greater than that of the third underflow stream, the second high gravitational separation having a higher force than the low gravitational separation;

fourth separation means for a gravitational separation of the third overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, wherein the fourth overflow stream, the first overflow stream or a combination thereof is suitable for use by an upgrader, the gravitational separation of the fourth separation means having a higher force than each of the first and the second high gravitational separations;

fifth separation means for a gravitational separation of a combination of a first portion of the fourth overflow stream and the first overflow stream into a fifth overflow stream suitable for use by the upgrader and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream, the gravitational separation of the fifth separation means having a lower force than the low gravitational separation; and

first recycling means for recycling a first portion of the fifth underflow stream upstream of the first separation means.

75. The system of claim 74 further comprising first combining means for combining a second portion of the fifth underflow stream with the first underflow stream.

76. The system of claim 75 further comprising second combining means for combining a third portion of the fifth underflow stream with the third overflow stream.

77. The system of claim 76 further comprising filtering means for filtering the third overflow stream or a combination of the third overflow stream with the third portion of the fifth underflow stream upstream of the fourth separation means.

78. The system of any one of claims 74 to 77 further comprising second recycling means for recycling the second overflow stream upstream of the first separation means.

79. The system of any one of claims 74 to 78 further comprising treating means for treating the bitumen feed with a solvent, a chemical additive or a combination thereof upstream of the first separation means.

80. A system for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the system comprising:

first separation means for a low gravitational separation of the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

second separation means for a first high gravitational separation of the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream, the first high gravitational separation having a higher force than the low gravitational separation;

third separation means for a second high gravitational separation of the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream, the second high gravitational separation having a higher force than the low gravitational separation;

fourth separation means for a gravitational separation of the second overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, wherein each of the first overflow stream and the fourth overflow stream is suitable for

use by an upgrader, the gravitational separation of the fourth separation means having a higher force than each of the first and the second high gravitational separations;

fifth separation means for a gravitational separation of a combination of a first portion of the fourth overflow stream and a first portion of the first overflow stream into a fifth overflow stream suitable for use by the upgrader and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream, the gravitational separation of the fifth separation means having a lower force than the low gravitational separation;

first recycling means for recycling the third overflow stream upstream of the first separation means; and

second recycling means for recycling a first portion of the fifth underflow stream upstream of the first separation means.

81. The system of claim 80 further comprising combining means for combining a second portion of the fifth underflow stream with the second overflow stream to form a combined stream.

82. The system of claim 81 further comprising filtering means for filtering the second overflow stream or the combined stream upstream of the fourth separation means.

83. The system of any one of claims 80 to 82 further comprising treating means for treating the bitumen feed with a solvent, a chemical additive or a combination thereof upstream of the first separation means.

84. A system for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the system comprising:

first separation means for a low gravitational separation of the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

second separation means for a first high gravitational separation of the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream, the first high gravitational separation having a higher force than the low gravitational separation;

third separation means for a second high gravitational separation of the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream, the second high gravitational separation having a higher force than the low gravitational separation;

fourth separation means for a gravitational separation of the second overflow stream and the third overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, the gravitational separation of the fourth separation means having a higher force than each of the first and the second high gravitational separations;

fifth separation means for a gravitational separation of the fourth overflow stream into a fifth overflow stream and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream, the gravitational separation of the fifth separation means having a higher force than each of the first and the second high gravitational separations;

combining means for combining the fifth overflow stream with the first overflow stream, wherein the first overflow stream, the fifth overflow stream or a combination thereof is suitable for use by an upgrader;

sixth separation means for a gravitational separation of the combination of the fifth overflow stream and the first overflow stream into a sixth overflow stream suitable for use by the upgrader and a sixth underflow stream, the sixth overflow stream having a bitumen concentration greater than that of the sixth underflow stream, the gravitational separation of the sixth separation means having a lower force than the low gravitational separation; and

recycling means for recycling a first portion of the sixth underflow stream upstream of the first separation means.

85. The system of claim 84 further comprising filtering means for filtering the fourth overflow stream upstream of the fifth separation means.

86. The system of claim 84 or 85 further comprising first combining means for combining a second portion of the sixth underflow stream with the second underflow stream upstream of the third separation means.

87. The system of claim 86 further comprising second combining means for combining a third portion of the sixth underflow stream with the second overflow stream and the third overflow stream upstream of the fourth separation means.

88. The system of claim 87 further comprising treating means for treating the bitumen feed with a solvent, a chemical additive or a combination thereof to form a treated bitumen feed upstream of the first separation means.

89. The system of claim 88 further comprising third combining means for combining a portion of the treated bitumen feed with the combination of the second overflow stream and the third overflow stream.

90. The system of claim 89 further comprising fourth combining means for combining a second solvent with the first underflow stream.

91. The system of claim 90 further comprising fifth combining means for combining a third solvent with the second underflow stream.

92. The system of claim 91 further comprising sixth combining means for combining a fourth solvent with the combination of the third portion of the sixth underflow stream with the second overflow stream and the third overflow stream upstream of the fourth separation means.

93. The system of claim 92 further comprising seventh combining means for combining a fifth solvent with the combination of the fifth overflow stream with the first overflow stream.

94. A system for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the system comprising:

first separation means for a low gravitational separation of the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

second separation means for a first high gravitational separation of the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream, the first high gravitational separation having a higher force than the low gravitational separation;

third separation means for a second high gravitational separation of the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream, the second high gravitational separation having a higher force than the low gravitational separation;

first combining means for combining the second overflow stream with the third overflow stream to form a combined overflow stream; and

fourth separation means for a first gravitational separation of the combined overflow stream to produce a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, the first gravitational separation of the fourth separation means having a higher force than each of the first and the second high gravitational separations.

95. The system of claim 94 further comprising second combining means for combining the fourth overflow stream with the first overflow stream, wherein the first overflow stream, the fourth overflow stream or a combination thereof is suitable for use by an upgrader.

96. The system of claim 94 or 95 further comprising filtering means for filtering the combined overflow stream upstream of the fourth separation means.

97. The system of claim 96 further comprising third combining means for combining a portion of the bitumen feed with the second overflow stream or the combined overflow stream upstream of the filtering means, the third separation means or a combination thereof.

98. The system of claim 94 further comprising fifth separation means for a second gravitational separation of the fourth overflow stream to produce a fifth overflow stream

and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream, the second gravitational separation of the fifth separation means having a higher force than each of the first and the second high gravitational separations.

99. The system of claim 98 wherein the second gravitational separation of the fifth separation means has a higher force than the first gravitational separation of the fourth separation means.

100. The system of claim 98 or 99 further comprising filtering means for filtering the fourth overflow stream upstream of the fifth separation means.

101. The system of any one of claims 98 to 100 further comprising second combining means for combining the fifth overflow stream with the first overflow stream, wherein the first overflow stream, the fifth overflow stream or a combination thereof is suitable for use by an upgrader.

102. The system of any one of claims 94 to 101 further comprising treating means for treating the bitumen feed with a solvent, a chemical additive or a combination thereof upstream of the first separation means.

103. A system for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the system comprising:

first separation means for a low gravitational separation of the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

second separation means for a first high gravitational separation of the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second

underflow stream, the first high gravitational separation having a higher force than the low gravitational separation;

third separation means for a second high gravitational separation of the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream, and combining the third overflow stream with the first underflow stream, the second high gravitational separation having a higher force than the low gravitational separation;

fourth separation means for a third high gravitational separation of the third underflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, and combining the fourth overflow stream with the second underflow stream, the third high gravitational separation having a higher force than the low gravitational separation;

fifth separation means for a gravitational separation of the first overflow stream into a fifth overflow stream and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream, the gravitational separation of the fifth separation means having a higher force than each of the first, the second and the third high gravitational separations; and

combining means for combining the fifth overflow stream with the first overflow stream, wherein the first overflow stream, the fifth overflow stream or a combination thereof is suitable for use by an upgrader.

104. The system of claim 103 further comprising grinding means for grinding the bitumen feed, treating means for treating the bitumen feed with a solvent, or a combination thereof upstream of the first separation means.

105. A system for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the system comprising:

first separation means for a low gravitational separation of the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

second separation means for a high gravitational separation of the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream, the high gravitational separation having a higher force than the low gravitational separation;

filtering means for filtering the second overflow stream to form a filtered overflow stream;

third separation means for a gravitational separation of the filtered overflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream, the gravitational separation of the third separation means having a higher force than the high gravitational separation; and

combining means for combining the third overflow stream with the first overflow stream, wherein the first overflow stream, the third overflow stream or a combination thereof is suitable for use by an upgrader.

106. The system of claim 105 further comprising fourth separation means upstream of the filtering means for a gravitational separation of the second overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, the gravitational separation of the fourth separation means having a higher force than the high

gravitational separation, wherein the fourth overflow stream is filtered by the filtering means.

107. The system of claim 105 or 106 wherein the second separation means comprises a first cyclone, a second cyclone and a centrifuge.

108. The system of any one of claims 105-107 further comprising treating means for treating the bitumen feed with a solvent upstream of the first separation means.

109. A system for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the system comprising:

first separation means for a low gravitational separation of the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

second separation means for a first high gravitational separation of the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream, the first high gravitational separation having a higher force than the low gravitational separation;

third separation means for a second high gravitational separation of the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream, the second high gravitational separation having a higher force than the low gravitational separation;

first combining means for combining the second overflow stream with the third overflow stream to form a combined overflow stream;

filtering means for filtering the combined overflow stream to form a filtered overflow stream;

fourth separation means for a gravitational separation of the filtered overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, the gravitational separation of the fourth separation means having a higher force than each of the first and the second high gravitational separations; and

second combining means for combining the fourth overflow stream with the first overflow stream, wherein the first overflow stream, the fourth overflow stream or a combination thereof is suitable for use by an upgrader.

110. The system of claim 109 further comprising fifth separation means upstream of the filtering means for a gravitational separation of the combined overflow stream into a fifth overflow stream and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream, the gravitational separation of the fifth separation means having a higher force than each of the first and the second high gravitational separations, wherein the fifth overflow stream is filtered by the filtering means.

111. The system of claim 109 or 110 wherein the second separation means comprises a first cyclone and a second cyclone.

112. The system of any one of claims 109-111 further comprising treating means for treating the bitumen feed with a solvent upstream of the first separation means.

113. A system for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the system comprising:

first separation means for a low gravitational separation of the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

second separation means for a high gravitational separation of the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream, the high gravitational separation having a higher force than the low gravitational separation;

third separation means for a first gravitational separation of the second overflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream, the first gravitational separation of the third separation means having a higher force than the high gravitational separation;

filtering means for filtering the third overflow stream to form a filtered overflow stream;

fourth separation means for a second gravitational separation of the filtered overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, the second gravitational separation of the fourth separation means having a higher force than the high gravitational separation; and

combining means for combining the fifth overflow stream with the first overflow stream, wherein the first overflow stream, the fifth overflow stream or a combination thereof is suitable for use by an upgrader.

114. The system of claim 113 wherein the second separation means comprises a first cyclone and a second cyclone.

115. The system of claim 113 or 114 further comprising treating means for treating the bitumen feed with a solvent upstream of the first separation means.

116. An apparatus for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the apparatus comprising:

an inclined plate separator for separating the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

a first cyclone for separating the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

a second cyclone for separating the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

a first gravity settler for separating a combination of the third overflow stream with the first overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, wherein the first overflow stream, the third overflow stream, the fourth overflow stream or a combination thereof is suitable for use by an upgrader; and

a first recycle path for recycling a first portion of the fourth underflow stream upstream of the inclined plate separator.

117. The apparatus of claim 116 further comprising a modulator for combining a second portion of the fourth underflow stream with the first underflow stream.

118. The apparatus of claim 116 or 117 further comprising a second recycle path for recycling the second overflow stream upstream of the inclined plate separator.

119. The apparatus of any one of claims 116 to 118 further comprising a treater for treating the bitumen feed with a solvent, a chemical additive or a combination thereof upstream of the inclined plate separator.

120. A apparatus for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the apparatus comprising:

an inclined plate separator for separating the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

a first cyclone for separating the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

a second cyclone for separating the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

a centrifuge for separating a combination of the second overflow stream with the third overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream;

a first modulator for combining the fourth overflow stream with the first overflow stream, wherein the first overflow stream, the fourth overflow stream or a combination thereof is suitable for use by an upgrader;

a gravity settler for separating a portion of the combination of the fourth overflow stream and the first overflow stream into a fifth overflow stream suitable for use by the upgrader and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream; and

a recycle path for recycling a first portion of the fifth underflow stream upstream of the inclined plate separator.

121. The apparatus of claim 120 further comprising a filter for filtering the combination of the second overflow stream with the third overflow stream upstream of the centrifuge.

122. The apparatus of claim 121 further comprising a second modulator for combining a second portion of the fifth underflow stream with the second overflow stream, or with the combination of the second overflow stream with the third overflow stream upstream of the centrifuge, upstream of the filter or a combination thereof.

123. The apparatus of any one of claims 120 to 122 further comprising a treater for treating the bitumen feed with a solvent, a chemical additive or a combination thereof upstream the inclined plate separator.

124. An apparatus for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the apparatus comprising:

an inclined plate separator for separating the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

a first cyclone for separating the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

a second cyclone for separating the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

a centrifuge for separating the third overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, wherein the fourth overflow stream, the first overflow stream or a combination thereof is suitable for use by an upgrader;

a gravity settler for separating a combination of a first portion of the fourth overflow stream and the first overflow stream into a fifth overflow stream suitable for use by the upgrader and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream; and

a first recycle path for recycling a first portion of the fifth underflow stream upstream of the inclined plate separator.

125. The apparatus of claim 124 further comprising a modulator for combining a second portion of the fifth underflow stream with the first underflow stream.

126. The apparatus of claim 125 further comprising a modulator for combining a third portion of the fifth underflow stream with the third overflow stream.

127. The apparatus of claim 126 further comprising a filter for filtering the third overflow stream or a combination of the third overflow stream with the third portion of the fifth underflow stream upstream of the centrifuge.

128. The apparatus of any one of claims 124 to 127 further comprising a second recycle path for recycling the second overflow stream upstream of the inclined plate separator.

129. The apparatus of any one of claims 124 to 128 further comprising a treater for treating the bitumen feed with a solvent, a chemical additive or a combination thereof upstream of the inclined plate separator.

130. An apparatus for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the apparatus comprising:

an inclined plate separator for separating the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

a first cyclone for separating the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

a second cyclone for separating the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

a centrifuge for separating the second overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, wherein each of the first overflow stream and the fourth overflow stream is suitable for use by an upgrader;

a gravity settler for separating a combination of a first portion of the fourth overflow stream and a first portion of the first overflow stream into a fifth overflow stream suitable for use by the upgrader and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream;

a first recycling path for recycling the third overflow stream upstream of the inclined plate separator; and

a second recycling path for recycling a first portion of the fifth underflow stream upstream of the inclined plate separator.

131. The apparatus of claim 130 further comprising a modulator for combining a second portion of the fifth underflow stream with the second overflow stream to form a combined stream.

132. The apparatus of claim 131 further comprising a filter for filtering the second overflow stream or the combined stream upstream of the centrifuge.

133. The apparatus of any one of claims 130 to 132 further comprising a treater for treating the bitumen feed with a solvent, a chemical additive or a combination thereof upstream of the inclined plate separator.

134. An apparatus for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the apparatus comprising:

an inclined plate separator for separating the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

a first cyclone for separating the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

a second cyclone for separating the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

a first centrifuge for separating the second overflow stream and the third overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream;

a second centrifuge for separating the fourth overflow stream into a fifth overflow stream and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream;

a modulator for combining the fifth overflow stream with the first overflow stream, wherein the first overflow stream, the fifth overflow stream or a combination thereof is suitable for use by an upgrader;

a gravity settler for separating the combination of the fifth overflow stream and the first overflow stream into a sixth overflow stream suitable for use by the upgrader and a sixth underflow stream, the sixth overflow stream having a bitumen concentration greater than that of the sixth underflow stream; and

a first recycle path for recycling a first portion of the sixth underflow stream upstream of the inclined plate separator.

135. The apparatus of claim 134 further comprising a filter for filtering the fourth overflow stream upstream of the second centrifuge.

136. The apparatus of claim 134 or 135 further comprising a first modulator for combining a second portion of the sixth underflow stream with the second underflow stream upstream of the second cyclone.

137. The apparatus of claim 136 further comprising a second modulator for combining a third portion of the sixth underflow stream with the second overflow stream and the third overflow stream upstream of the first centrifuge.

138. The apparatus of claim 137 further comprising a treater for treating the bitumen feed with a solvent, a chemical additive or a combination thereof to form a treated bitumen feed upstream of the inclined plate separator.

139. The apparatus of claim 138 further comprising a third modulator for combining a portion of the treated bitumen feed with the combination of the second overflow stream and the third overflow stream.

140. The apparatus of claim 139 further comprising a fourth modulator for combining a second solvent with the first underflow stream.

141. The apparatus of claim 140 further comprising a fifth modulator for combining a third solvent with the second underflow stream.

142. The apparatus of claim 141 further comprising a sixth modulator for combining a fourth solvent with the combination of the third portion of the sixth underflow stream with the second overflow stream and the third overflow stream upstream of the first centrifuge.

143. The apparatus of claim 142 further comprising a seventh modulator for combining a fifth solvent with the combination of the fifth overflow stream with the first overflow stream.

144. An apparatus for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the apparatus comprising:

an inclined plate separator for separating the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

a first cyclone for separating the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

a second cyclone for separating the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

a first modulator for combining the second overflow stream with the third overflow stream to form a combined overflow stream; and

a first centrifuge for separating the combined overflow stream to produce a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream.

145. The apparatus of claim 144 further comprising a second modulator for combining the fourth overflow stream with the first overflow stream, wherein the first overflow stream, the fourth overflow stream or a combination thereof is suitable for use by an upgrader.

146. The apparatus of claim 144 or 145 further comprising a filter for filtering the combined overflow stream upstream of the first centrifuge.

147. The apparatus of claim 146 further comprising a third modulator for combining a portion of the bitumen feed with the second overflow stream or the combined overflow stream upstream of the filter, the first centrifuge or a combination thereof.

148. The apparatus of claim 144 further comprising a second centrifuge for separating the fourth overflow stream into a fifth overflow stream and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream.

149. The apparatus of claim 148 further comprising a second modulator for combining the fifth overflow stream with the first overflow stream, wherein the fifth overflow stream, the first overflow stream or a combination thereof is suitable for use by an upgrader.

150. The apparatus of claim 148 or 149 further comprising a filter for filtering the fourth overflow stream upstream of the second centrifuge.

151. The apparatus of any one of claims 144 to 150 further comprising a treater for treating the bitumen feed with a solvent, a chemical additive or a combination thereof upstream of the inclined plate separator.

152. An apparatus for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the apparatus comprising:

an inclined plate separator for separating the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

a first cyclone for separating the first underflow stream into a second overflow stream and a second underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

a second cyclone for separating the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream, and combining the third overflow stream with the first underflow stream;

a third cyclone for separating the third underflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen

concentration greater than that of the fourth underflow stream, and combining the fourth overflow stream with the second underflow stream;

a centrifuge for separating the first overflow stream into a fifth overflow stream and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream; and

a modulator for combining the fifth overflow stream with the first overflow stream, wherein the first overflow stream, the fifth overflow stream or a combination thereof is suitable for use by an upgrader.

153. The apparatus of claim 152 further comprising a grinder for processing the bitumen feed, a treater for treating the bitumen feed with a solvent, or a combination thereof upstream of the inclined plate separator.

154. An apparatus for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the apparatus comprising:

an inclined plate separator for separating the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

a first cyclone for separating the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

a filter for filtering the second overflow stream to form a filtered overflow stream;

a centrifuge for separating the filtered overflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream; and

a modulator for combining the third overflow stream with the first overflow stream, wherein the first overflow stream, the third overflow stream or a combination thereof is suitable for use by an upgrader.

155. The apparatus of claim 154 further comprising a second cyclone upstream of the filter for separating the second underflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream, wherein the second overflow stream, the fourth overflow stream or a combination thereof is filtered by the filter.

156. The apparatus of claim 154 or 155 further comprising a treater for treating the bitumen feed with a solvent upstream of the inclined plate separator.

157. An apparatus for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the apparatus comprising:

an inclined plate separator for separating the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

a first cyclone for separating the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

a second cyclone for separating the second underflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

a first modulator for combining the second overflow stream with the third overflow stream to form a combined overflow stream;

a filter for filtering the combined overflow stream to form a filtered overflow stream;

a first centrifuge for separating the filtered overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream; and

a second modulator for combining the fourth overflow stream with the first overflow stream, wherein the first overflow stream, the fourth overflow stream or a combination thereof is suitable for use by an upgrader.

158. The apparatus of claim 157 further comprising a second centrifuge upstream of the filter for separating the combined overflow stream into a fifth overflow stream and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream, wherein the fifth overflow stream is filtered by the filter.

159. The apparatus of claim 157 or 158 further comprising a treater for treating the bitumen feed with a solvent upstream of the inclined plate separator.

160. An apparatus for concentrating hydrocarbons in a bitumen feed comprising bitumen, water and solids, the apparatus comprising:

an inclined plate separator for separating the bitumen feed into a first overflow stream and a first underflow stream, the first overflow stream having a bitumen concentration greater than that of the first underflow stream;

a first cyclone for separating the first underflow stream into a second overflow stream and a second underflow stream, the second overflow stream having a bitumen concentration greater than that of the second underflow stream;

a first centrifuge for separating the second overflow stream into a third overflow stream and a third underflow stream, the third overflow stream having a bitumen concentration greater than that of the third underflow stream;

a filter for filtering the third overflow stream to form a filtered overflow stream;

a second centrifuge for separating the filtered overflow stream into a fourth overflow stream and a fourth underflow stream, the fourth overflow stream having a bitumen concentration greater than that of the fourth underflow stream; and

a modulator for combining the fourth overflow stream with the first overflow stream, wherein the first overflow stream, the fourth overflow stream or a combination thereof is suitable for use by an upgrader.

161. The apparatus of claim 160 further comprising a second cyclone upstream of the first centrifuge for separating the second underflow stream into a fifth overflow stream and a fifth underflow stream, the fifth overflow stream having a bitumen concentration greater than that of the fifth underflow stream, wherein the second overflow stream, the fifth overflow stream or a combination thereof is separated by the first centrifuge.

162. The apparatus of claim 160 or 161 further comprising a treater for treating the bitumen feed with a solvent upstream of the inclined plate separator.



FIG. 1

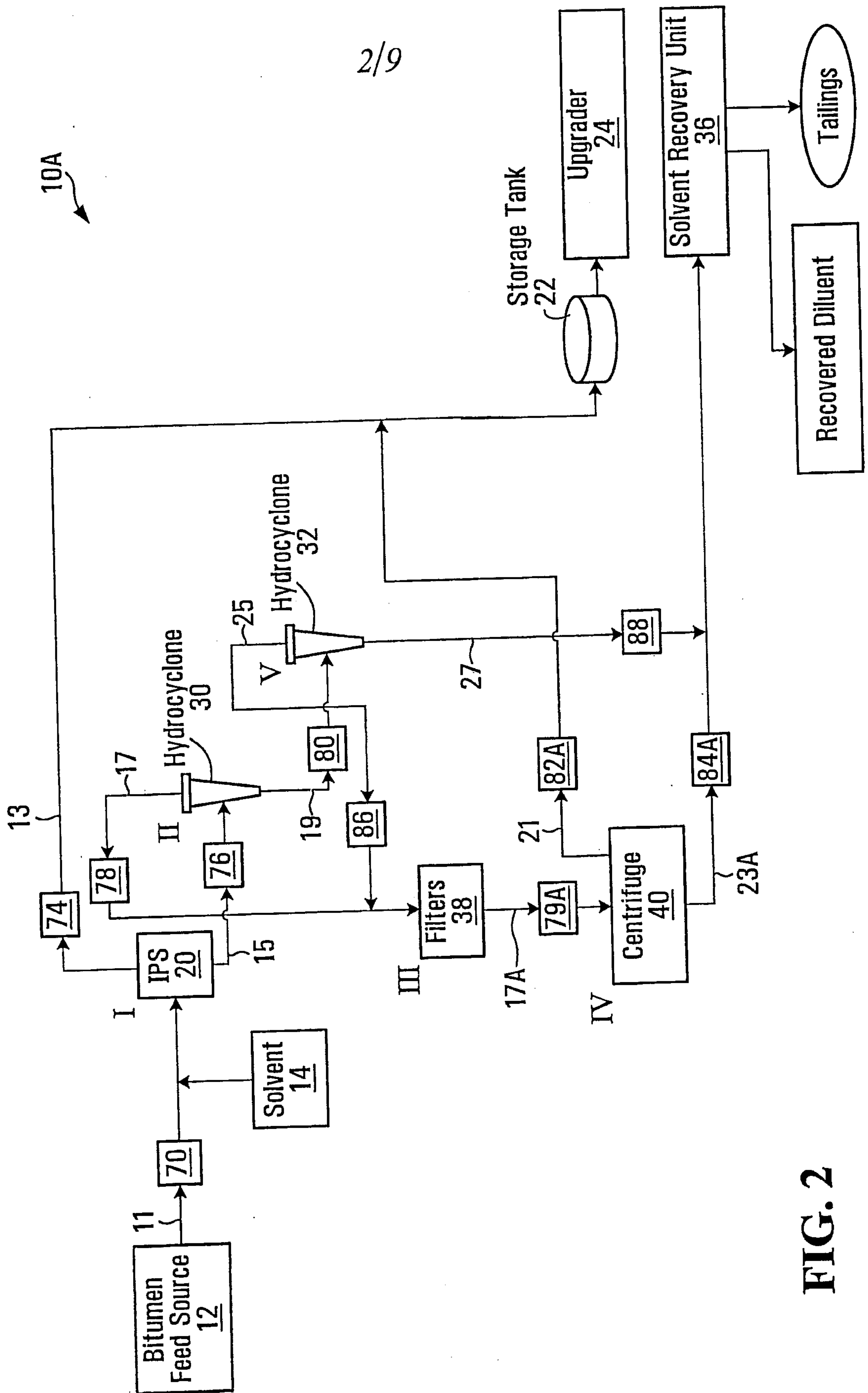


FIG. 2

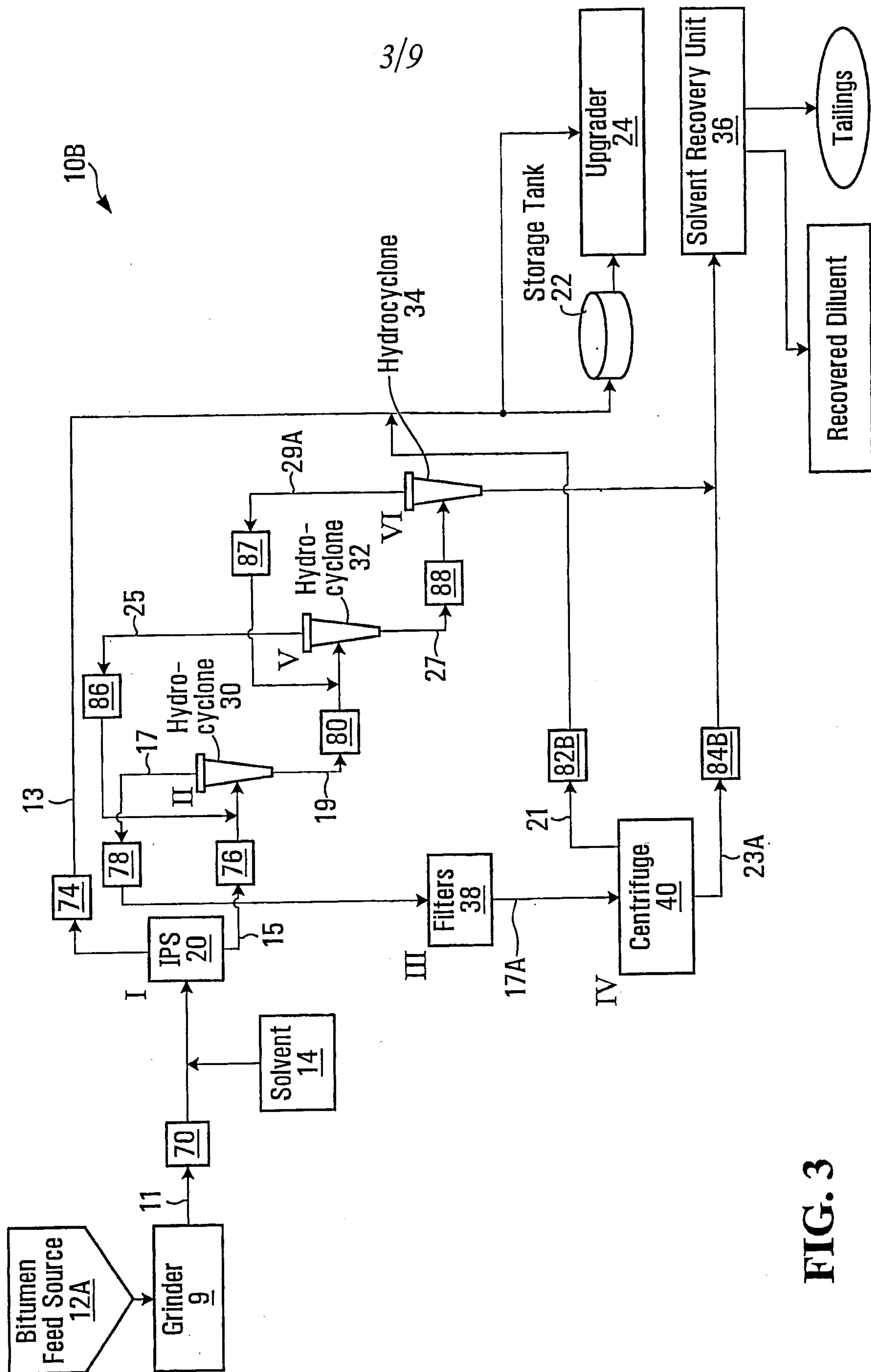
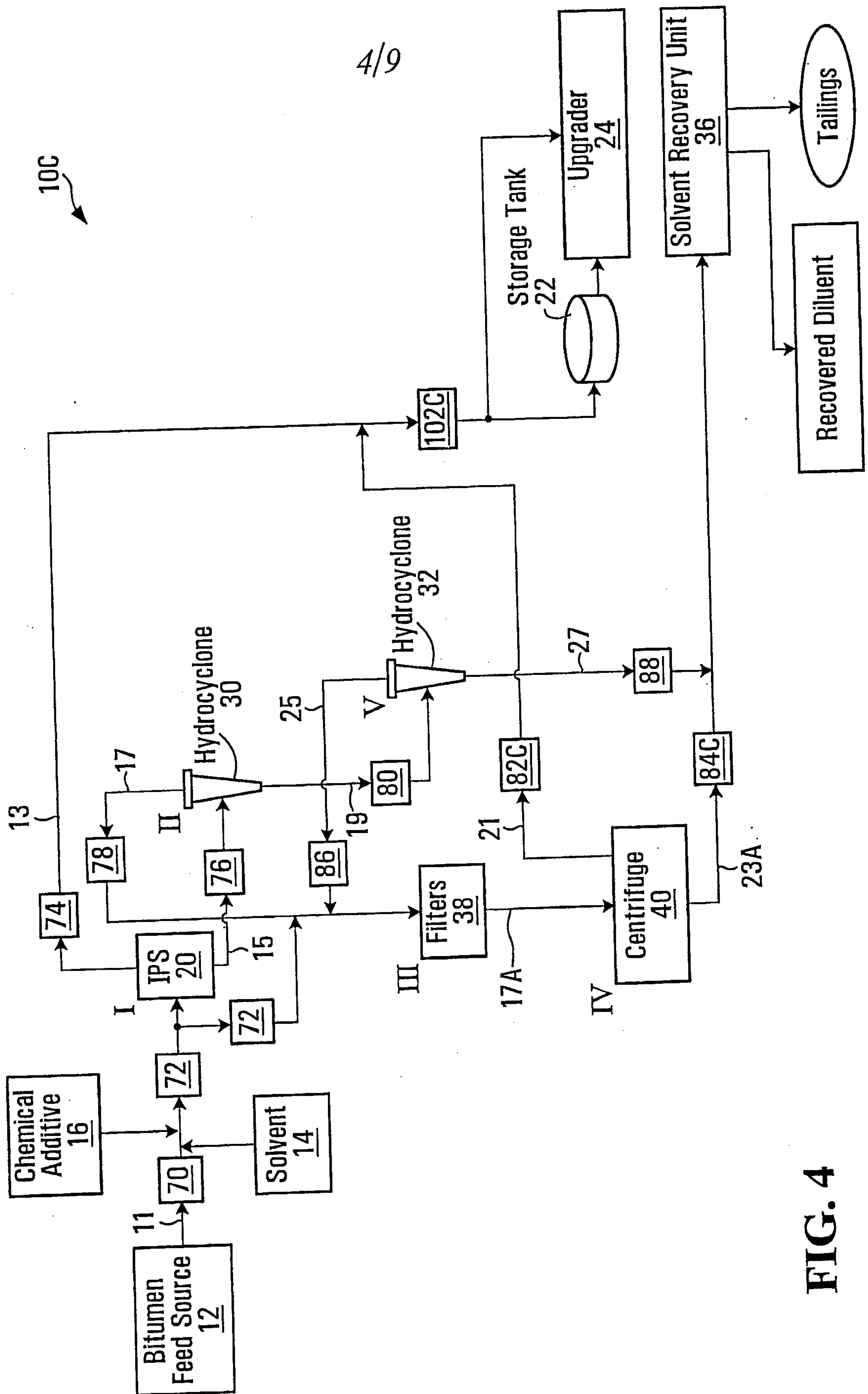
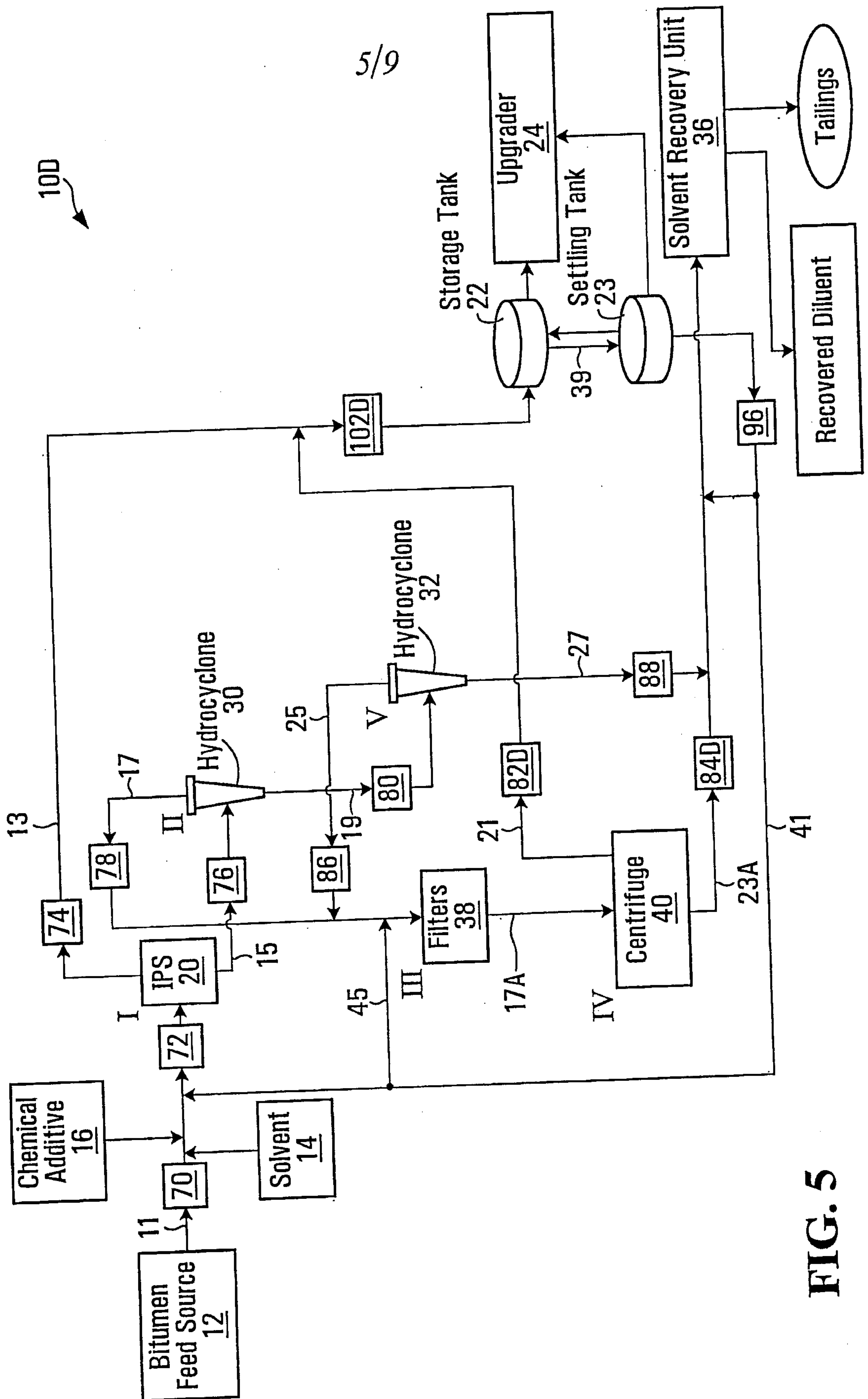


FIG. 3





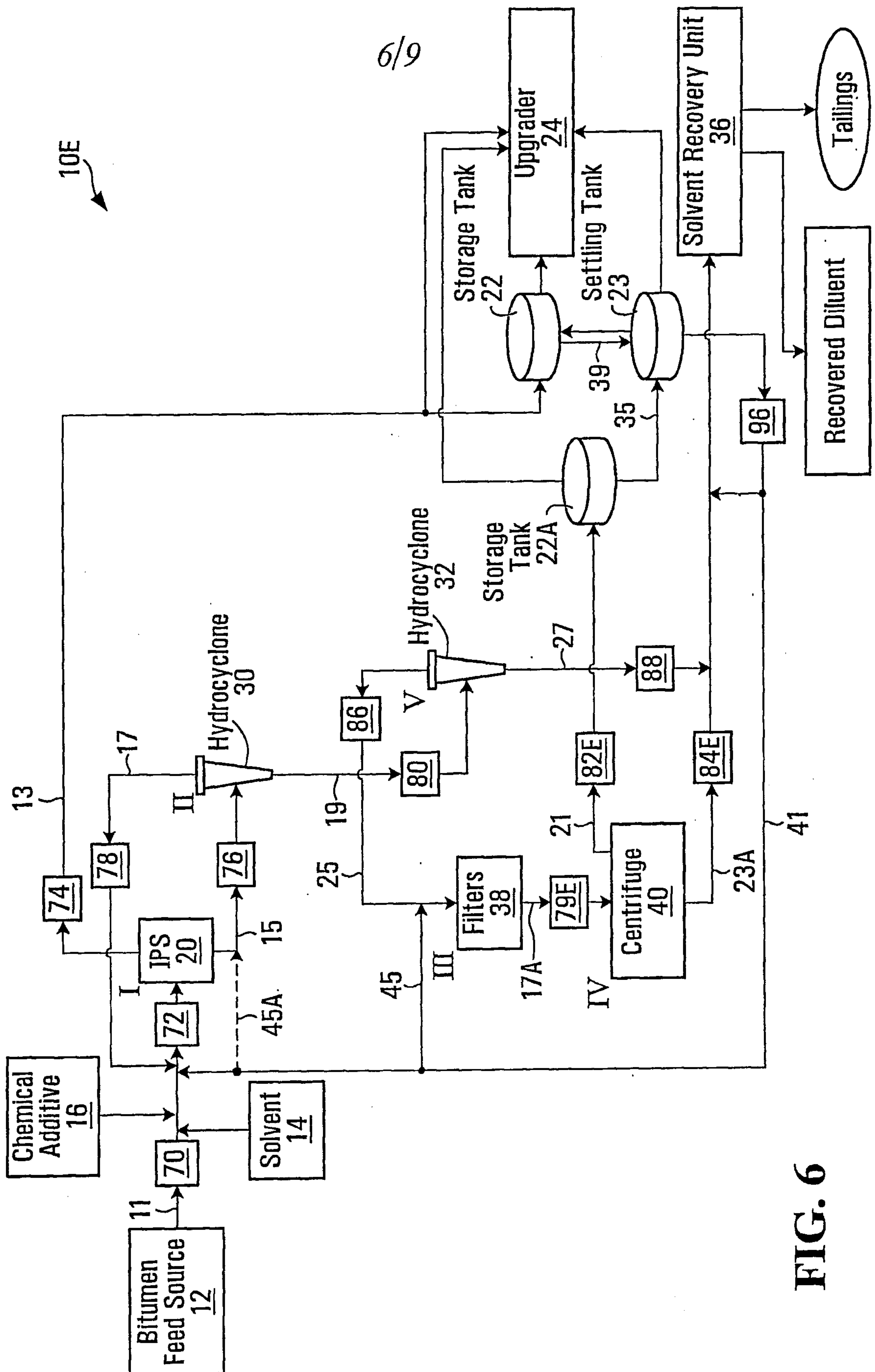


FIG. 6

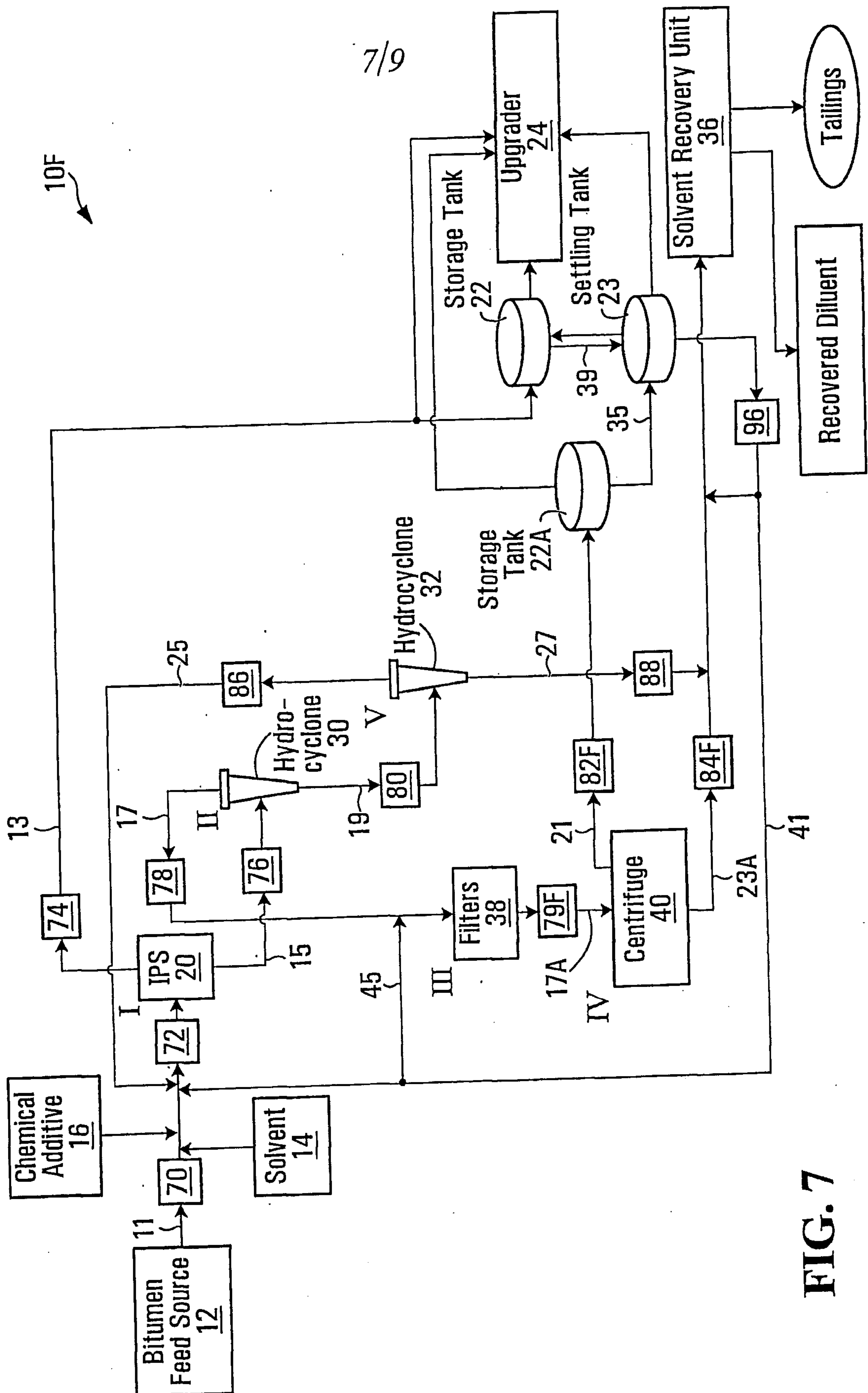


FIG. 7



FIG. 8

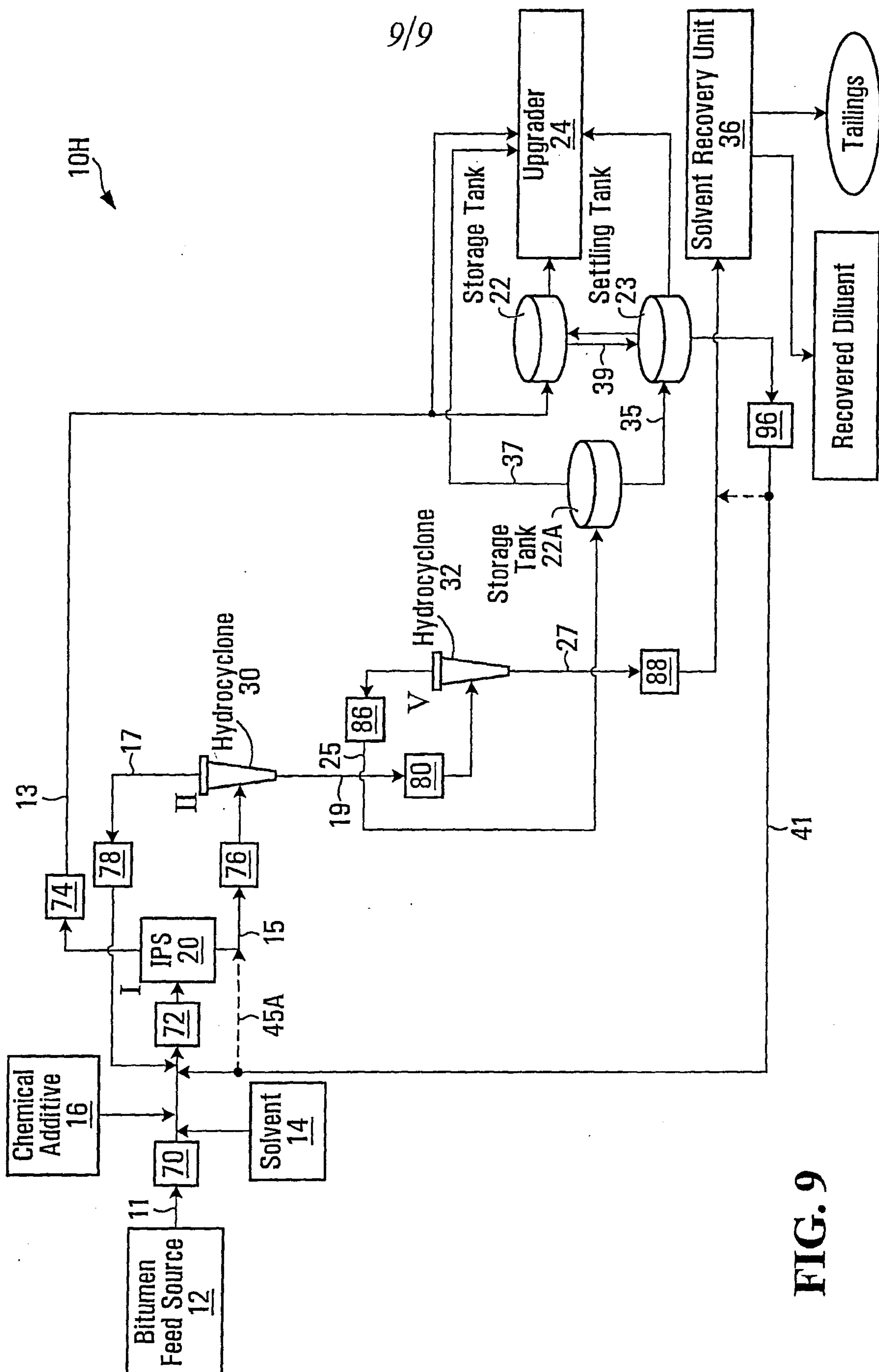


FIG. 9

