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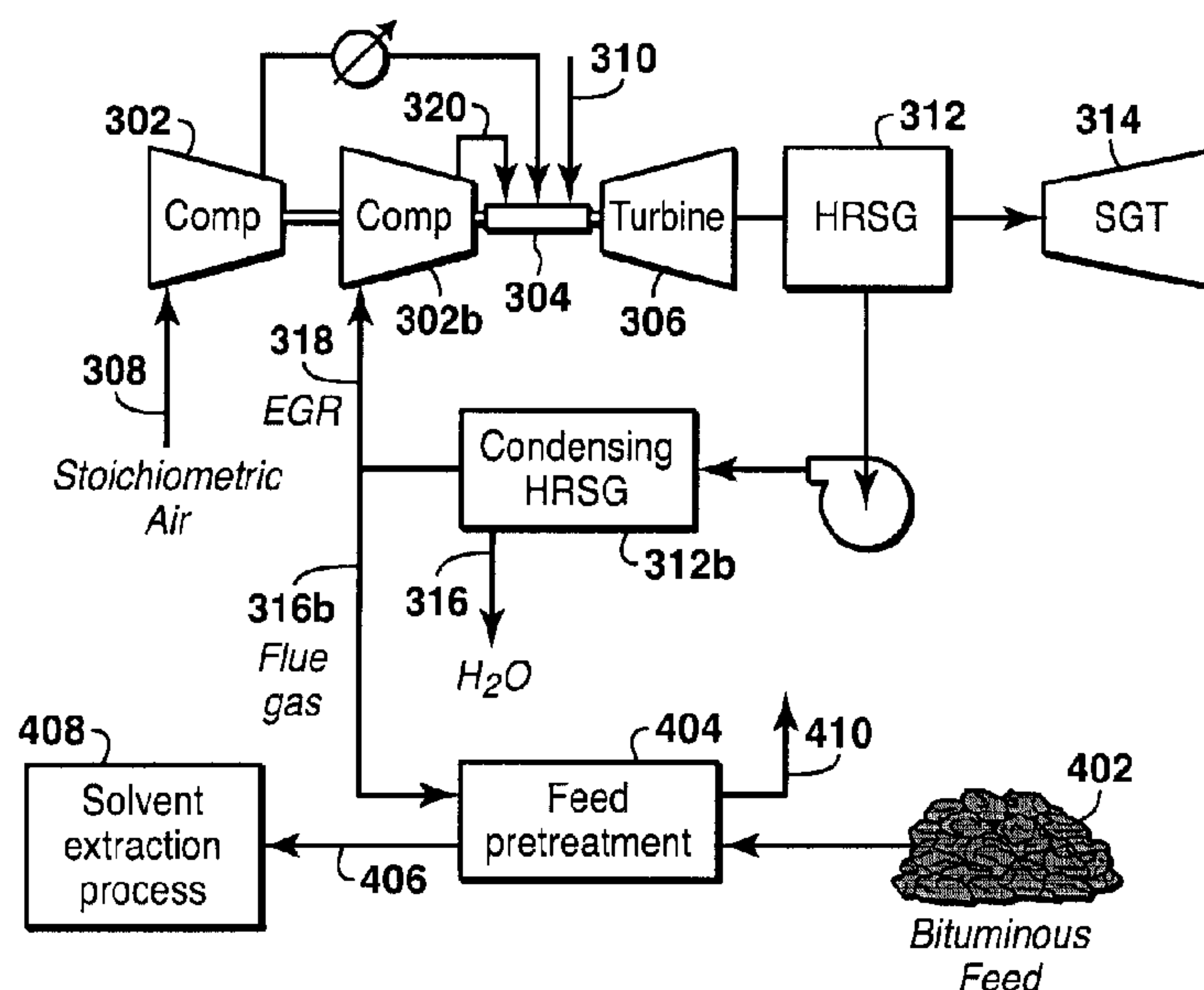
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(54) Titre : PROCÉDE DE TRAITEMENT DE MATIÈRE PREMIÈRE BITUMINEUSE

(54) Title: METHODS FOR PROCESSING A BITUMINOUS FEED



(57) Abrégé/Abstract:

A method for processing a bituminous feed may include providing the bituminous feed having a bituminous feed water content outside of a target range; selecting a flue gas from a combustion process having a flue gas water content that is different than the bituminous feed water content; forming a resultant bituminous feed with a resultant bituminous feed water content within the target range by contacting the bituminous feed and the flue gas; and passing the resultant bituminous feed to a solvent extraction process for extracting bitumen from the resultant bituminous feed.

ABSTRACT

A method for processing a bituminous feed may include providing the bituminous feed having a bituminous feed water content outside of a target range; selecting a flue gas from a combustion process having a flue gas water content that is different than the bituminous feed water content; forming a resultant bituminous feed with a resultant bituminous feed water content within the target range by contacting the bituminous feed and the flue gas; and passing the resultant bituminous feed to a solvent extraction process for extracting bitumen from the resultant bituminous feed.

METHODS FOR PROCESSING A BITUMINOUS FEED

CROSS REFERENCE TO RELATED APPLICATION

[0001] The present application is a divisional application of Canadian Patent Application No. 2,863,488 filed on September 11, 2014.

BACKGROUND

Field of Disclosure

[0002] The disclosure relates generally to the field of oil sands processing. More specifically, the present disclosure relates to methods for processing a bituminous feed.

Description of Related Art

[0003] This section is intended to introduce various aspects of the art, which may be associated with the present disclosure. This discussion is believed to assist in providing a framework to facilitate a better understanding of particular aspects of the present disclosure. Accordingly, it should be understood that this section should be read in this light, and not necessarily as admissions of prior art.

[0004] Modern society is greatly dependent on the use of hydrocarbon resources for fuels and chemical feedstocks. Hydrocarbons are generally found in subsurface formations that can be termed “reservoirs.” Removing hydrocarbons from the reservoirs depends on numerous physical properties of the subsurface formations, such as the permeability of the rock containing the hydrocarbons, the ability of the hydrocarbons to flow through the subsurface formations, and the proportion of hydrocarbons present, among other things. Easily harvested sources of hydrocarbons are dwindling, leaving less accessible sources to satisfy future energy needs. As the costs of hydrocarbons increase, the less accessible sources become more economically attractive.

[0005] Recently, the harvesting of oil sands to remove heavy oil has become more economical. Hydrocarbon removal from oil sands may be performed by several techniques.

For example, a well can be drilled to an oil sand reservoir and steam, hot air, solvents, or a combination thereof, can be injected to release the hydrocarbons. The released hydrocarbons may be collected by wells and brought to the surface. In another technique, strip or surface mining may be performed to access the oil sands, which can be treated with hot water, steam or solvents to extract the heavy oil. This other technique may be referred to as a water-based extraction process (WBE). The WBE is a commonly used process to extract bitumen from mined oil sands. In another technique, a non-water-based extraction process can be used to treat the strip or surface mined oil sands. The non-water-based extraction process may be referred to as a solvent based extraction process. The commercial application of a solvent based extraction process has, for various reasons, eluded the oil sands industry. A major challenge associated with the solvent based extraction process is the tendency of fine particles within the oil sands to hamper the separation of solids from the heavy oil (e.g., bitumen) extracted.

[0006] A solids agglomeration process has been proposed for use in the solvent based extraction process. The solid agglomeration process was coined Solvent Extraction Spherical Agglomeration (SESA). A description of the SESA process can be found in Sparks *et al.*, *Fuel* 1992(71); pp. 1349-1353. Previously described methodologies for SESA have not been commercially adopted. In general, the SESA process involves mixing oil sands with a hydrocarbon solvent to form an oil sands slurry, adding an aqueous bridging liquid to the oil sands slurry to form a mixture, agitating the mixture in a slow and controlled manner to nucleate particles, and continuing such agitation so as to permit these nucleated particles to form larger multi-particle spherical agglomerates for removal. The aqueous bridging liquid may be water or an aqueous solution since the solids of oil sands are mostly hydrophilic and water is immiscible to hydrocarbon solvents. The aqueous bridging liquid preferentially wets the solids. With the right amount of the aqueous bridging liquid and suitable agitation of the slurry; the aqueous bridging liquid displaces the suspension liquid on the surface of the solids. As a result of interfacial forces among three phases (i.e. the aqueous bridging liquid, the suspension liquid, and the solids), fine particles within the solids consolidate into larger, compact agglomerates that are more readily separated from the suspension liquid.

[0007] The SESA process described by Meadus *et al.* in U.S. Patent No. 4,057,486 involves combining solvent extraction with solids agglomeration to achieve dry tailings suitable for direct mine refill. Organic material is separated from oil sands by mixing the oil sands material with an organic solvent to form a slurry, after which an aqueous bridging liquid is added in an amount of 8 to 50 weight percent (wt.%) of the feed mixture. By using controlled agitation, solid particles from oil sands come into contact with the aqueous bridging liquid and adhere to each other to form macro-agglomerates with a mean diameter of 2 millimeters (mm) or greater. The agglomerates are more easily separated from the organic solvent compared to un-agglomerated solids. The agglomerates are referred to as macro-agglomerates because they result from the consolidation of both fine particles and coarse particles that make up the oil sands. Fine particles may be defined as less than 44 microns (μm); coarse particles may be defined as greater than 44 μm . The aforementioned ranges may include any number bounded by the aforementioned ranges.

[0008] U.S. Patent No. 4,057,486 describes methods for using the fine particles within oil sands and an aqueous bridging liquid to promote the consolidation of the coarse particles into compact macro-agglomerates from which the bulk of hydrocarbons was excluded and are easily separated from the hydrocarbon liquid by simple screening. For oil sands with fines of less than 15 wt. %, the resulting agglomerates show poor strength and a substantial amount of hydrocarbons entrained within their pores. The inability of this macro-agglomeration process to produce agglomerates of similar solid-liquid separation characteristics regardless of oil sands feed grade, is a severe limitation. The inability can be mitigated to a certain degree by using sludge (water and fine particle slurry) as the aqueous bridging liquid. When sludge is used as the aqueous bridging liquid, the addition of the same amount of sludge per unit weight of oil sands feed will result in the production of agglomerates of the same drainage properties regardless of oil sands quality. The use of sludge, however, introduces other challenges such as the fact that the appropriate sludge may not be readily available at the mine site. Furthermore, the use of sludge as the aqueous bridging liquid leads to macro-agglomerates that are more prone to entrapment of hydrocarbons within the pores of the macro-agglomerates.

[0009] U.S. Patent No. 4,719,008 (Sparks *et al.*) describes a process to apply SESA to varying ore grade qualities by a micro-agglomeration procedure in which the fine particles of the oil sands are consolidated to produce agglomerates with a similar particle size distribution to the coarser particles of the oil sands. Since rapid agglomeration and agglomerates of a large size can lead to bitumen recovery losses owing to entrapment of extracted bitumen within the agglomerated solids, the level of aqueous bridging liquid is kept as low as possible commensurate with achieving economically viable solid liquid separations. This micro-agglomeration process requires careful control of the aqueous bridging liquid to solids ratio. If the amount of aqueous bridging liquid present in the oil sands slurry is larger than the required amount, rapid growth of agglomerates can lead to bitumen recovery losses owing to entrapment of bitumen within the agglomerated solids. However, if the amount of aqueous bridging liquid present is too low, insufficient agglomeration increases the amount of dispersed fines in the liquid suspension which hampers solids-liquid separation. An aqueous bridging liquid to solids ratio between 0.08 and 0.15 was identified as a preferred range for micro-agglomeration of the solids within the oil sands slurry. Maintaining the aqueous bridging liquid to solids ratio within this narrow range during the actual field operation of the agglomeration process would be a challenge. The low aqueous bridging liquid scenario can be mitigated by careful control of the amount of additional aqueous bridging liquid added to the slurry. The high aqueous bridging liquid scenario is more challenging to mitigate than the low aqueous bridging liquid scenario because removing the aqueous bridging liquid from the slurry is difficult. Additionally, adding dry solids to the slurry to decrease the aqueous bridging liquid to solids ratio may significantly reduce the efficiency of the overall solvent extraction process.

[0010] U.S. Patent No. 4,139,450 (Hanson *et al.*) describes removing water from an oil sands slurry to avoid the formation of oil-water-silt suspensions that are difficult to process. The water is removed by initially mixing the oil sands slurry with solvent having sufficient energy to evaporate the water. The solvent may be but is not limited to an aromatic solvent such as toluene with boiling points between 82 degrees (°) Celsius (C) and 138°C . The solvent may be mixed with the oil sands as a vapor phase with some of the solvent vapor transferring heat to the oil sands by condensation to evaporate the water. The water vapor may be removed

by gas stripping where the stripping gas may comprise non-condensed solvent vapor and/or inert gases such as natural gas or nitrogen gas.

[0011] U.S. Patent Publication No. 2010/0288677 (Bohnert *et al.*) describes a system for solvent extraction of bitumen from a bituminous feed where the bituminous feed is dried within a drying zone prior to contact with the solvent. Examples of suitable dryers identified in the publication include drum dryers, disc dryers, belt dryers, paddle dryers, fluidized beds, venture dryers, and rotary dryers.

[0012] U.S. Patent Publication No. 2010/0236991 (Hastings) describes a system and method for solvent extraction of bitumen from a bituminous feed. The system uses a feed stock pre-treatment process using a vibratory load hopper to provide a bituminous feed to the solvent extraction process with a predetermined moisture content. Hastings describes that it is preferable to reduce the bituminous feed moisture content to approximately 3 wt.%. The control of the moisture content of the bituminous feed, according to Hastings, may allow for improved process reliability and less system down-time.

[0013] U.S. Patent No. 4,331,532 (Bose) describes an aqueous extraction process where flue gas is used for heating and sweeping a bituminous sand in order to reduce the water content within the bituminous sand. Bose found that the reduction of the water content of the bituminous sand reduced the amount of solids that remained suspended in the aqueous phase after the aqueous extraction process.

[0014] U.S. Patent Publication No. 2011/0127197 (Blackbourn *et al.*) describes the use of flue gas to purge oxygen from a bituminous feed prior to directing the feed to a solvent extraction process.

[0015] Solvent extraction is sensitive to water content, bitumen content, fines content, and asphaltene content. It is desirable to provide methods for processing a bituminous feed to yield a bituminous feed having properties which are suitable for solvent extraction.

SUMMARY

[0016] It is an object of the present disclosure to provide methods for processing a bituminous feed. The methods may yield a bituminous feed having properties which are suitable for solvent extraction.

[0017] A method for processing a bituminous feed may comprise: a) providing a first bituminous feed having at least one first bituminous feed property falling outside of a target range; b) selecting a second bituminous feed having at least one second bituminous feed property that has a different value than the at least one first bituminous feed property; c) selecting a ratio of the first bituminous feed to the second bituminous feed; d) forming a third bituminous stream, having at least one third bituminous stream property falling within the target range, by combining the first bituminous feed and the second bituminous feed at the ratio; and e) passing the third bituminous feed to a solvent extraction process for extracting bitumen from the third bituminous feed.

[0018] A method for processing a bituminous feed may comprise: a) providing the bituminous feed having a bituminous feed water content outside of a target range; b) selecting a flue gas from a combustion process having a flue gas water content that is different than the bituminous feed water content; c) forming a resultant bituminous feed with a resultant bituminous feed water content within the target range by contacting the bituminous feed and the flue gas; and d) passing the resultant bituminous feed to a solvent extraction process for extracting bitumen from the resultant bituminous feed.

[0019] The foregoing has broadly outlined the features of the present disclosure so that the detailed description that follows may be better understood. Additional features will also be described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] These and other features, aspects and advantages of the disclosure will become apparent from the following description, appending claims and the accompanying drawings, which are briefly described below.

[0021] Figure 1 is a graph illustrating the relationship between bitumen recovery from a solvent extraction with solids agglomeration process and water content in an oil sand slurry.

[0022] Figure 2 is a flow chart illustrating pretreatment of a bituminous feed by combining the feed with one or more additional bituminous feeds.

[0023] Figure 3a is a schematic of a natural gas combined cycle (NGCC) system.

[0024] Figure 3b is schematic of an NGCC system combined with a compressed recycle stream.

[0025] Figure 4 is a schematic of a pretreatment of a bituminous feed in order to decrease the bituminous feed's water content.

[0026] Figure 5 is a schematic of a pretreatment of a bituminous feed in order to increase the bituminous feed's water content.

[0027] Figure 6 is a flow chart of a process for pretreating a bituminous feed.

[0028] Figure 7 is a flow chart of a process for pretreating a bituminous feed.

[0029] It should be noted that the figures are merely examples and no limitations on the scope of the present disclosure are intended thereby. Further, the figures are generally not drawn to scale, but are drafted for purposes of convenience and clarity in illustrating various aspects of the disclosure.

DETAILED DESCRIPTION

[0030] For the purpose of promoting an understanding of the principles of the disclosure, reference will now be made to the features illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the disclosure is thereby intended. Any alterations and further modifications, and any further applications of the principles of the disclosure as described herein are contemplated as would normally occur to one skilled in the art to which the disclosure relates. It will be apparent to those skilled in the relevant art that some features that are not relevant to the present disclosure may not be shown in the drawings for the sake of clarity.

[0031] At the outset, for ease of reference, certain terms used in this application and their meaning as used in this context are set forth below. To the extent a term used herein is not defined below, it should be given the broadest definition persons in the pertinent art have given that term as reflected in at least one printed publication and issued patent. Further, the present processes are not limited by the usage of the terms shown below, as all equivalents, synonyms, new developments and terms or processes that serve the same or a similar purpose are considered to be within the scope of the present disclosure.

[0032] A “hydrocarbon” is an organic compound that primarily includes the elements of hydrogen and carbon, although nitrogen, sulfur, oxygen, metals, or any number of other elements may be present in small amounts. Hydrocarbons generally refer to components found in heavy oil or in oil sands. However, the techniques described are not limited to heavy oils but may also be used with any number of other reservoirs to improve gravity drainage of liquids. Hydrocarbon compounds may be aliphatic or aromatic, and may be straight chained, branched, or partially or fully cyclic.

[0033] “Bitumen” is a naturally occurring heavy oil material. Generally, it is the hydrocarbon component found in oil sands. Bitumen can vary in composition depending upon the degree of loss of more volatile components. It can vary from a very viscous, tar-like, semi-solid material to solid forms. The hydrocarbon types found in bitumen can include aliphatics, aromatics, resins, and asphaltenes. A typical bitumen might be composed of:

- 19 weight (wt.) % aliphatics (which can range from 5 wt. % - 30 wt. %, or higher);
- 19 wt. % asphaltenes (which can range from 5 wt. % - 30 wt. %, or higher);
- 30 wt. % aromatics (which can range from 15 wt. % - 50 wt. %, or higher);
- 32 wt. % resins (which can range from 15 wt. % - 50 wt. %, or higher); and
- some amount of sulfur (which can range in excess of 7 wt. %).

In addition, bitumen can contain some water and nitrogen compounds ranging from less than 0.4 wt. % to in excess of 0.7 wt. %. The percentage of the hydrocarbon found in bitumen can vary. The term “heavy oil” includes bitumen as well as lighter materials that may be found in a sand or carbonate reservoir.

[0034] “Heavy oil” includes oils which are classified by the American Petroleum Institute (“API”), as heavy oils, extra heavy oils, or bitumens. The term “heavy oil” includes bitumen. Heavy oil may have a viscosity of about 1,000 centipoise (cP) or more, 10,000 cP or more, 100,000 cP or more, or 1,000,000 cP or more. In general, a heavy oil has an API gravity between 22.3° API (density of 920 kilograms per meter cubed (kg/m^3) or 0.920 grams per centimeter cubed (g/cm^3)) and 10.0° API (density of 1,000 kg/m^3 or 1 g/cm^3). An extra heavy oil, in general, has an API gravity of less than 10.0° API (density greater than 1,000 kg/m^3 or 1 g/cm^3). For example, a source of heavy oil includes oil sand or bituminous sand, which is a combination of clay, sand, water and bitumen. The recovery of heavy oils is based on the viscosity decrease of fluids with increasing temperature or solvent concentration. Once the viscosity is reduced, the mobilization of fluid by steam, hot water flooding, or gravity is possible. The reduced viscosity makes the drainage quicker and therefore directly contributes to the recovery rate.

[0035] The term “bituminous feed” refers to a stream derived from oil sands that requires downstream processing in order to realize valuable bitumen products or fractions. The bituminous feed is one that comprises bitumen along with undesirable components. Undesirable components may include but are not limited to clay, minerals, coal, debris and water. The bituminous feed may be derived directly from oil sands, and may be, for example, raw oil sands ore. Further, the bituminous feed may be a feed that has already realized some initial processing but nevertheless requires further processing. Also, recycled streams that comprise bitumen in combination with other components for removal as described herein can be included in the bituminous feed. A bituminous feed need not be derived directly from oil sands, but may arise from other processes. For example, a waste product from other extraction processes which comprises bitumen that would otherwise not have been recovered may be used as a bituminous feed.

[0036] “Fine particles” are generally defined as those solids having a size of less than 44 microns (μm), that is, material that passes through a 325 mesh (44 micron). The aforementioned range includes any number within the range.

[0037] “Coarse particles” are generally defined as those solids having a size of greater than 44 microns (μm). The aforementioned range includes any number within the range.

[0038] A “solvent-based recovery process” or “solvent extraction process” includes any type of hydrocarbon recovery process that uses a solvent, at least in part, to enhance the recovery, for example, by diluting or lowering a viscosity of the hydrocarbon. Solvent-based recovery processes may be used in combination with other recovery processes, such as, for example, thermal recovery processes. In a solvent-based recovery process, a solvent is injected into a subterranean reservoir. The solvent may be heated or unheated prior to injection, may be a vapor or liquid and may be injected with or without steam. Solvent-based recovery processes may include, but are not limited to, solvent assisted cyclic steam stimulation (SA-CSS), solvent assisted steam assisted gravity drainage (SA-SAGD), solvent assisted steam flood (SA-SF), vapor extraction process (VAPEX), heated vapor extraction process (H-VAPEX), cyclic solvent process (CSP), heated cyclic solvent process (H-CSP), solvent flooding, heated solvent flooding, liquid extraction process, heated liquid extraction process, solvent-based extraction recovery process (SEP), thermal solvent-based extraction recovery processes (TSEP), and any other such recovery process employing solvents either alone or in combination with steam. A solvent-based recovery process may be a thermal recovery process if the solvent is heated prior to injection into the subterranean reservoir. The solvent-based recovery process may employ gravity drainage.

[0039] “Macro-agglomeration” is the consolidation of both fine particles and coarse particles that make up the oil sands. Macro-agglomerates may have a mean diameter of 2 millimeters (mm) or greater. The diameter of the macro-agglomerates may include any number within or bounded by the preceding range.

[0040] “Micro-agglomeration” is the consolidation of fine particles that make up the oil sands. Micro-agglomerates may have a mean diameter of less than 2 millimeters (mm). The diameter of the micro-agglomerates may include any number within the preceding range.

[0041] The terms “approximately,” “about,” “substantially,” and similar terms are intended to have a broad meaning in harmony with the common and accepted usage by those

of ordinary skill in the art to which the subject matter of this disclosure pertains. It should be understood by those of skill in the art who review this disclosure that these terms are intended to allow a description of certain features described and claimed without restricting the scope of these features to the precise numeral ranges provided. Accordingly, these terms should be interpreted as indicating that insubstantial or inconsequential modifications or alterations of the subject matter described and are considered to be within the scope of the disclosure.

[0042] The articles “the”, “a” and “an” are not necessarily limited to mean only one, but rather are inclusive and open ended so as to include, optionally, multiple such elements.

[0043] “At least one,” in reference to a list of one or more entities should be understood to mean at least one entity selected from any one or more of the entity in the list of entities, but not necessarily including at least one of each and every entity specifically listed within the list of entities and not excluding any combinations of entities in the list of entities. This definition also allows that entities may optionally be present other than the entities specifically identified within the list of entities to which the phrase “at least one” refers, whether related or unrelated to those entities specifically identified. Thus, as a non-limiting example, “at least one of A and B” (or, equivalently, “at least one of A or B,” or, equivalently “at least one of A and/or B”) may refer, to at least one, optionally including more than one, A, with no B present (and optionally including entities other than B); to at least one, optionally including more than one, B, with no A present (and optionally including entities other than A); to at least one, optionally including more than one, A, and at least one, optionally including more than one, B (and optionally including other entities). In other words, the phrases “at least one,” “one or more,” and “and/or” are open-ended expressions that are both conjunctive and disjunctive in operation. For example, each of the expressions “at least one of A, B and C,” “at least one of A, B, or C,” “one or more of A, B, and C,” “one or more of A, B, or C” and “A, B, and/or C” may mean A alone, B alone, C alone, A and B together, A and C together, B and C together, A, B and C together, and optionally any of the above in combination with at least one other entity.

[0044] Where two or more ranges are used, such as but not limited to 1 to 5 or 2 to 4, any number between and/or inclusive of these ranges is implied.

[0045] Solvent extraction with solids agglomeration is sensitive to the quantity of aqueous bridging liquid present in the slurry during solids agglomeration. When the amount of aqueous bridging liquid in the slurry is insufficient, agglomeration does not capture enough of the dispersed fine particles in the liquid suspension, which hampers solid-liquid separation. The amount of aqueous bridging liquid in the slurry may be insufficient when a water to solids ratio of aqueous bridging liquid to slurry is less than 0.05. The ratio may vary with ore grade and the method by which the aqueous bridging liquid is introduced. The aqueous bridging liquid may interchangeably be referred to as bridging liquid. The insufficient aqueous bridging liquid scenario can be mitigated by careful control of the amount of additional aqueous bridging liquid added to the slurry. In the case when excess aqueous bridging liquid is present in the slurry, rapid growth of agglomerates can lead to a reduction in bitumen recovery owing to entrapment of the bitumen within the pores of the agglomerated solids. Rapid growth of agglomerates refers to agglomeration occurring faster than dissolution. The amount of aqueous bridging liquid in the slurry may be excess when a water to solids ratio of aqueous bridging liquid to slurry is more than 0.10. The ratio may vary with ore grade and the method by which the aqueous bridging liquid is introduced. The amount of aqueous bridging liquid can be substantially in excess such that agglomerates fail to form and the solids turn into a paste with an extremely low permeability. The amount of aqueous bridging liquid being substantially in excess may lead to costly process delays. The amount of aqueous bridging liquid being substantially in excess may lead to shut-downs due to the failure of the solid-liquid separation process.

[0046] Figure 1 illustrates the relationship between bitumen recovery from a solvent extraction with solids agglomeration process and water content in the oil sand slurry, using cyclohexane as the solvent. The broken line (100) at 90% bitumen recovery shows a target recovery. Three levels of agglomeration are illustrated. First, un-agglomerated solids (102) provide good bitumen dissolution, poor bitumen filtration, and poor bitumen recovery. Second, micro-agglomeration (104) provides good bitumen dissolution, good bitumen filtration, and good bitumen recovery. Third, macro-agglomeration (106) provides good bitumen dissolution, good bitumen filtration, and poor bitumen recovery. Since agglomeration occurs more rapidly

than dissolution, by extracting (dissolving) most of the bitumen prior to agglomeration, bitumen inclusion may be reduced. In other words, less bitumen may be entrained when agglomeration occurs more rapidly than dissolution.

[0047] When the water content in the slurry is insufficient, agglomeration does not capture enough of the dispersed fines in the liquid suspension. The amount of water in the slurry may be insufficient when a water to solids ratio is less than 0.05. Agglomeration not capturing enough of the dispersed fines in the liquid suspension may hamper solid-liquid separation, and may result in a low fines capture. A low fines capture may be defined as less than 80% fines capture. The aforementioned range may include any number within the aforementioned range. Figure 1 shows that for a water to solids ratio of below approximately 6 wt. %, un-agglomerated fines can cause the filter and/or filter bed to plug, leading to poor bitumen recovery.

[0048] When excess water is present in the slurry, rapid growth of agglomerates can lead to a reduction in bitumen recovery owing to entrapment of the bitumen within the agglomerated solids. The amount of water in the slurry may be excess when a water to solids ratio is more than 0.10. Figure 1 shows that as the water to solids ratio increases above approximately 10 wt. %, bitumen recovery decreases. As Figure 1 shows, the decrease in bitumen recovery is most likely due to bitumen inclusion within the larger agglomerates. The use of sludge with excess water as the aqueous bridging liquid may lead to larger macro-agglomerates that are more prone to entrapment of bitumen within the pores of the macro-agglomerates.

[0049] The solvent to bitumen ratios within a solvent extraction process remain within prescribed ranges irrespective of the bitumen content of the bituminous feed entering the solvent extraction process. An example of a ratio of solvent to bitumen to be selected as a target ratio during bitumen extraction may be approximately 2:1. A ratio as low as 0.75:1 may be acceptable during the initial dissolution of bitumen since the higher bitumen content may assist in the rate of bitumen dissolution. A ratio as high as 3:1 may be acceptable during solid-liquid separation since the higher solvent content may reduce the viscosity of the oil sand slurry. In other words, the ratio may range from 0.75:1 to 3:1. The aforementioned range may include

any ratio within and/or bounded by the range. A solvent extraction process running continuously with a bituminous feed with a high bitumen content may result in a lowering of the solvent to bitumen ratio to values where the higher viscosity of the bitumen extract inhibits solid liquid separation. Whether or not a given bitumen content is high may depend on factors such as but not limited to slurry density, slurry temperature, asphaltene content, and solvent wash rate. Conversely, a solvent extraction process running continuously with a bituminous feed with a low bitumen content may result in a rise of the solvent to bitumen ratio to values that reduce the rate and the amount of bitumen dissolution and/or may result in undesirable asphaltene precipitation. Whether or not a given bitumen content is low may depend on factors such as but not limited to slurry density, slurry temperature, asphaltene content, and solvent wash rate. One way to manage solvent to bitumen ratio is to maintain an excess supply of bitumen that can be used in areas within the solvent extraction process where the solvent-to-bitumen ratio is above the desired value. This way of managing may not be desired; it may require an inventory of bitumen which is expensive to maintain in order to ensure proper control of the solvent to bitumen ratio.

[0050] Macro-agglomeration processes can generally operate in the presence of a much higher aqueous bridging liquid content than micro-agglomeration processes. However, macro-agglomeration is more suitable for bituminous feeds with a solids composition of greater than 15 wt. % fine solids. One way to introduce a higher concentration of fines into the agglomeration process is to use sludge (water and fine particle slurry) as the aqueous bridging liquid. When sludge is used as the aqueous bridging liquid, the addition of the same amount of sludge per unit weight of bituminous feed may result in the production of macro-agglomerates of the same drainage properties regardless of the fines content of the bituminous feed. Sludge, however, may not be available at a solvent extraction mine site.

[0051] The present disclosure describes methods and systems for processing a bituminous feed to yield a bituminous feed having properties which are suitable for solvent extraction. The methods and systems involve processing one or more bituminous feeds and passing a third bituminous feed or a resultant bituminous feed to a solvent extraction process. Accordingly, the methods and systems may be referred to as a “pretreatment” to solvent

extraction. The methods provide a solvent extraction feed that is more suitable for the solvent extraction process than conventional solvent extraction feeds. For example, the methods and systems may provide a solvent extraction feed having a water content within a target range. Figures 1-7 depict methods and systems of the present disclosure.

[0052] The methods and systems may include providing (602) a first bituminous feed (202) having at least one first bituminous feed property falling outside of a target range. The first bituminous feed (202) may be a problematic bituminous feed. The at least one first bituminous feed property may interchangeably be referred to as at least one property of the first bituminous feed. The first bituminous feed property may be at least one of a water content, a bitumen content, a fines content of solids, and an asphaltene content. The water content may be a particularly suitable property to measure since water acts as the aqueous bridging liquid that controls the agglomeration process.

[0053] The first bituminous feed (202) may comprise excess water that makes it unsuitable for the solvent extraction process. The first bituminous feed (202) may include, but is not limited to, mined oil sands with a water content of greater than 6 wt. %, bituminous feeds derived from a water-based extraction process, or a bituminous feed from a solvent-based extraction process. The first bituminous feed (202) may be one of a stream from a water-based extraction process, a tailings stream from a water-based oil sands extraction process, mature fine tailings (MFT) or paraffinic froth treatment (PFT) tailings.

[0054] The at least one first bituminous feed property may be measured by a measuring apparatus (204). When the at least one first bituminous feed property is a water content, the water content measurements may be taken by a near-infrared (NIR) analyzer, Karl-Fischer titration, Dean-Stark analysis (D-S), microwave sensors, NMR (nuclear magnetic resonance), or hyperspectral imaging. When the at least one first bituminous feed property is a bitumen content, the bitumen content measurements may be taken by NIR, D-S, or hyperspectral imaging. When the at least one first bituminous feed property is a fines content of solids, the fines content measurements may be taken by sieving, FBRM (focused beam reflectance measurement), PVM (particle visual measurement), inline particle size microscopy, laser diffraction, sedimentation methods (e.g. sedigraph), optical microscopy, electrical impedance

(e.g. coulter counter), or hyperspectral imaging. When the at least one first bituminous feed property is a solvent to bitumen ratio, the solvent to bitumen ratio may be measured by a densitometer, an NIR analyzer, or hyperspectral imaging. When the at least one first bituminous feed property is an asphaltene content, the asphaltene content measurement in bitumen may be measured by NIR, optical spectroscopy, fluorescence depolarization spectroscopy, n-paraffin titration, or an asphaltene analyzer.

[0055] The methods and systems may include selecting (604) a second bituminous feed (203) having at least one second bituminous feed property. The at least one second bituminous feed property may interchangeably be referred to as at least one property of the second bituminous feed. The at least one second bituminous feed property may be at least one of a water content, a bitumen content, a fines content of solids, and an asphaltene content. The water content may be a particularly suitable property to measure since water acts as the aqueous bridging liquid that controls the agglomeration process. The at least one second bituminous feed property may have a different value than the at least one first bituminous feed property.

[0056] Selecting the second bituminous feed (203) may include exposing the bituminous feed, processed by the methods and systems, to the environment. Exposing the bituminous feed to the environment may evaporate water from the bituminous feed. Evaporating water from the bituminous feed may lower a water content of the bituminous feed. The second bituminous feed (203) may be the bituminous feed after being evaporated. In this way, when it is desired for the second bituminous feed (203) to have a low water bitumen content feed, the second bituminous feed (203) can be made from the bituminous feed using evaporation.

[0057] The at least one second bituminous feed property may be measured by a measuring apparatus (206). When the at least one second bituminous feed property is a water content, the water content measurements may be taken by a near-infrared (NIR) analyzer, Karl-Fischer titration, Dean-Stark analysis (D-S), microwave sensors, NMR (nuclear magnetic resonance), or hyperspectral imaging. When the at least one second bituminous feed property is a bitumen content, the bitumen content measurements may be taken by NIR, D-S, or hyperspectral imaging. When the at least one second bituminous feed property is a fines content

of solids, the fines content measurements may be taken by sieving, FBRM (focused beam reflectance measurement), PVM (particle vision measurement), laser diffraction, sedimentation methods (e.g. sedigraph), optical microscopy, canty probes, electrical impedance (e.g. coulter counter), or hyperspectral imaging. When the at least one second bituminous feed property is a solvent to bitumen ratio, the solvent to bitumen ratio may be measured by a densitometer, an NIR analyzer, or hyperspectral imaging. When the at least one second bituminous feed property is an asphaltene content, the asphaltene content measurement in bitumen may be measured by NIR, or an asphaltene analyzer.

[0058] The methods and systems may include selecting (606) a ratio of the first bituminous feed (202) to the second bituminous feed (203). By way of illustration, the following numerical example is provided. Consider that a third bituminous feed having a water content of 5 wt. % is desired and that a first bituminous feed has a water content of 30 wt. % while a second bituminous feed has a water content of 1 wt. %. The following equation may be used:

[0059] $(\text{weight fraction of 1}^{\text{st}} \text{ stream}) \times (\text{wt. \% water in 1}^{\text{st}} \text{ stream}) + (\text{weight fraction of 2}^{\text{nd}} \text{ stream}) \times (\text{wt. \% water in 2}^{\text{nd}} \text{ stream}) = (\text{weight fraction of 3}^{\text{rd}} \text{ stream}) \times (\text{wt. \% water in 3}^{\text{rd}} \text{ stream});$

[0060] Using “A” as the weight fraction of the 1st stream, “1-A” as the weight fraction of the 2nd stream, and “1” as the weight fraction of the third stream, the equation becomes:

[0061] $A \times (\text{wt. \% water in 1}^{\text{st}} \text{ stream}) + (1-A) \times (\text{wt. \% water in 2nd stream}) = (1) \times (\text{wt. \% water in 3rd stream});$ which, in our example, becomes:

[0062] $30A + 1 - A = 5;$ solving for A provides:

[0063] $A = 4/29,$ meaning that 4 parts (by weight) 1st stream may be combined with 25 parts (by weight) 2nd stream to yield a third bituminous feed with a water content of 5 wt. %. In addition to water content, other properties such as bitumen content, fines content of solids, and asphaltene content, may equally be selected by adjusting in this way.

[0064] The methods and systems may include forming (608) a third bituminous feed (210) by combining the first bituminous feed and the second bituminous feed at the ratio. The

first bituminous feed (202) and the second bituminous feed (203) may be combined (208) in a proportion. The first bituminous feed (202) and the second bituminous feed (203) may be combined (208) in a proportion based on the measurements taken at measuring apparatus (204) and measuring apparatus (206). The first bituminous feed (202) and the second bituminous feed (203) may be combined in a combining apparatus (208) in a proportion that may yield a third bituminous feed (210) having at least one third bituminous stream property falling within the target range. The combining apparatus (208) may be any suitable combining apparatus (208) such as but not limited to a crusher, a tumble drum, a SAG (Semi-Autogenous Grinding) mill, a pump-box, a superpot, or a pipe junction, such as those described in CA 2,810,730 (Spence et al.).

[0065] The third bituminous feed (210) may interchangeably be referred to as a resulting bituminous feed or a third bituminous stream. The third bituminous feed (210) may have the at least one third bituminous stream property falling within the target range. The at least one third bituminous stream property may interchangeably be referred to as at least one property of the third bituminous stream. The third bituminous stream property may be at least one of a water content, a bitumen content, a fines content of solids and an asphaltene content. The water content may be a particularly suitable property to measure since water acts as the aqueous bridging liquid that controls the agglomeration process. The at least one third bituminous stream property may be suitable for solvent extraction. The at least one third bituminous stream property may be more suitable for solvent extraction than the at least one first bituminous feed property and/or the at least one second bituminous feed property.

[0066] Forming the third bituminous feed (210) by combining the first bituminous feed (202) and the second bituminous feed (203) may include adjusting the blending proportions of the first bituminous feed (202) with the second bituminous feed (203) to form the third bituminous feed (210) having the at least one third bituminous stream property falling within the target range. Combining the first bituminous feed (202) with the second bituminous feed (203) may include mixing the first bituminous feed stream (202) with the second bituminous feed stream (203). The second bituminous feed stream (203) may have a lower water content than the first bituminous feed (202). The water content of the third bituminous feed (210) may

be more suitable for a solvent extraction process than the first bituminous feed (202) and the second bituminous feed (203). Combining the first bituminous feed (202) with the second bituminous feed (203) may include mixing the first bituminous feed (202) with the second bituminous feed (203) to adjust the solvent to bitumen ratio of a downstream oil sand slurry following solvent addition. Combining the first bituminous feed (202) with the second bituminous feed (203) may include mixing the first bituminous feed (202) with the second bituminous feed (203) to adjust the fines content of the solids with the third bituminous feed (210); the third bituminous feed (210) may be suitable for a solvent extraction with solids agglomeration process. Combining the first bituminous feed (202) with the second bituminous feed (203) may include mixing the first bituminous feed (202) with the second bituminous feed (203) to reduce variability in the third bituminous feed (210); the third bituminous feed (210) may enter the solvent extraction process. Combining the first bituminous feed (202) and the second bituminous feed (203) may include combining the first bituminous feed (202) and the second bituminous feed (203) to produce the third bituminous feed (210) with a ratio of solvent to bitumen at a level to prevent any precipitation or limit precipitation of asphaltenes to less than 10 weight (wt)% of an asphaltene content in the solvent extraction process. To produce the ratio of solvent to bitumen, the amount of solvent added to the solvent extraction may be adjusted and/or the bitumen content of the third bituminous stream may be adjusted, as described above in the numerical example involving adjusting water content. Combining the first bituminous feed (202) and the second bituminous feed (203) may reduce the feed variability entering the solvent extraction process; combining the first bituminous feed (202) and the second bituminous feed (203) may result in a reduced feed variability in the third bituminous feed (210) to that present in the first bituminous feed (202) and/or the second bituminous feed (203) before combining the first bituminous feed (202) and the second bituminous feed (203). Having less feed variability is beneficial to provide a more uniform process and product.

[0067] The methods and systems may include passing (610) the third bituminous stream to a solvent extraction process for extracting bitumen from the third bituminous feed (210). Bitumen may be extracted from the third bituminous feed (210) during the solvent extraction

process (212). The third bituminous feed (210) may be passed to a solvent extraction process (212) forming an oil sands slurry, for instance by a pipeline.

[0068] Passing the third bituminous feed (203) to the solvent extraction process (212) may not preclude earlier solvent extraction. For example, the first bituminous stream, the second bituminous stream, and/or the third bituminous stream may be solvent extracted to some extent prior to passing the third bituminous stream to the solvent extraction process.

[0069] The solvent extraction process may be a solvent extraction with solids agglomeration process. The solvent extraction process may use a paraffinic solvent. The solids agglomeration process may produce macro-agglomerates or micro-agglomerates. Non-limiting examples of a solvent extraction processes that are solvent extraction with solids agglomeration processes, include those described in the background of the present disclosure and CA 2,724,806 (“Adeyinka *et al.*”).

[0070] Adeyinka *et al.* discloses extracting bitumen from oil sands in a manner that employs solvent. A first solvent is combined with a bituminous feed derived from oil sand to form an initial slurry. The initial slurry is separated into a fines solids stream and a coarse solids stream, where the majority of the fine solids within the oil sands are in the fine solids stream and the majority of the coarse solids with the oils sands are in the coarse solids stream. The coarse solids steam can be separated into coarse solids and a first low solids bitumen extract stream. Aqueous bridging liquid is added to the fine solids stream to agglomerate the fine solids in the stream and form an agglomerated slurry. The agglomerated slurry can be separated into agglomerates and a second low solids bitumen extract stream. A second solvent can be mixed with the low solids bitumen extract streams to form a solvent-bitumen low solids mixture, which can then be separated further into low grade and high grade bitumen extracts. Recovery of solvent from the low grade and high grade extracts is conducted to produce bitumen products of commercial value.

[0071] Adeyinka *et al.* also describes agglomeration of an initial slurry without separation into a fines solids stream and a coarse solids stream. A first solvent is combined with a bituminous feed to form an initial slurry. The solids from the initial slurry are

agglomerated to form an agglomerated slurry comprising agglomerates and a low solids bitumen extract. The low solids bitumen extract is separated from the agglomerated slurry. A second solvent is mixed with the low solids bitumen extract to form a solvent-bitumen low solids mixture, which can then be separated further into low grade and high grade bitumen extracts. Recovery of solvent from the low grade and high grade extracts is conducted to produce bitumen products of commercial value. The methods and systems of the present disclosure may be suitable for use with the solvent extraction process described by Adeyinka *et al.* because the methods and systems of the present disclosure may be used to reduce the amount of aqueous bridging liquid present in a bituminous feed. In the solvent extraction process described by Adeyinka *et al.*, the bitumen may first be dissolved from the bituminous feed prior to agglomeration in order to prevent (or limit) the agglomeration process from reducing the rate of bitumen dissolution into the extraction liquor. In Adeyinka *et al.*, the amount of aqueous bridging liquid in the oil sands slurry may be reduced in order to prevent (or limit) the amount of coarse solids that are agglomerated. In Adeyinka *et al.*, a reduction in coarse solids agglomeration may result in an increase in bitumen recovery by limiting bitumen entrapment only to the pores of the agglomerates formed with the fine solids.

[0072] The pretreatment may be used to control the amount of bridging liquid present in the oil sands slurry. Mined oil sands from the Athabasca region have a typical water content of 1 to 6 wt. %. At this level of water, additional aqueous bridging liquid may be added to the oil sands slurry in order to optimize the solvent extraction with solid agglomeration process. The amount of water in the oil sands can be much greater than 6 wt. %. For example, the oil sands may be mined from a location of unusually high water saturation, or the oil sands after being mined may be exposed to precipitation that increases the water content of the oil sands. As described above, this excess level of water can negatively impact the solvent extraction process. The wet bituminous feed – interchangeably referred to as a first bituminous feed – may be mixed with a dry bituminous feed – interchangeably referred to as a second bituminous feed – in order to yield a third bituminous feed with a suitable water content for the solvent extraction process. The first and second bituminous feeds may be combined in order to produce the third bituminous feed with a water content in a range of 2 to 25 %, or 4 to 8% wt. %, by

combining the two streams in an appropriate proportion. The water content of the third bituminous feed may be any number within or bounded by the preceding water content ranges for the third bituminous feed. The dry bituminous feed may be directly mined or may be rendered dry by exposing it to the environment where the water in the bituminous feed can evaporate over time.

[0073] The pretreatment may be used to control the solvent to bitumen ratio of the oil sands slurry in the solvent extraction process. It is typical in a solvent extraction process that the amount of solvent recycled from the solvent recovery unit is set by the rate of solids flow into the solvent extraction process and operation conditions (e.g. preferred slurry density and solvent to bitumen ratio). Mined oil sands from the Athabasca region have a typical solids content of approximately 85 wt. % regardless of the amount of bitumen saturation within the oil sands. For this reason, it may be preferred that the amount of solvent recycle remains constant in the solvent extraction process. However, a constant solvent recycle can result in a solvent to bitumen ratio in the oil sand slurry that is not in the target range depending on the bitumen content of the bituminous feed. If the solvent to bitumen ratio is lower than a target range, the higher viscosity bitumen extract may inhibit solid liquid separation. If the solvent to bitumen ratio is higher than a target range, the rate and the amount of bitumen dissolution may be reduced and/or may result in undesirable asphaltene precipitation. The changes in the solvent to bitumen ratio can be limited by blending bituminous feeds in order to reduce that variability of bitumen flow into the solvent extraction process. The second bituminous feed may be used to adjust a solvent to bitumen ratio in the solvent extraction process to within a range of 0.5-5.0 or 1.5-2.5, by blending the two streams in an appropriate proportion. To adjust the solvent to bitumen ratio, the bitumen content of the third bituminous stream may be adjusted, as described above in the numerical example involving adjusting water content. The solvent to bitumen ratio may be any suitable ratio within or bounded by the preceding solvent to bitumen ratios. These ranges may be suitable for the solvent extraction process.

[0074] The pretreatment may be used to control the amount of fines processed by the solvent extraction with solids agglomeration process. The macro-agglomeration process can operate in the presence of much higher aqueous bridging liquid content than the micro-

agglomeration process. The macro-agglomeration is more suitable for bituminous feeds with a solids composition of greater 15 wt. % fines. A first bituminous feed stream with a low fines content can be mixed with a second bituminous feed stream with a fines content greater than 15 wt. % in order to obtain a third bituminous feed stream that is more suitable for the macro-agglomeration of solids. Low grade oil sands, which are typically discarded in water-based extraction of oil sands, may be a suitable second bituminous feed. The first and second bituminous feeds may be combined in order to produce a third bituminous feed with the fines content in a range of 5-50 or 15-40 wt. %, by blending the two streams in an appropriate proportion as, for example, described above in the numerical example involving adjusting water content. The fines content may be any suitable number within or bounded by the preceding fines content ranges.

[0075] Methods and systems for processing a bituminous feed to yield a bituminous feed having properties suitable for solvent extraction may include methods and systems where water content within the bituminous feed is controlled by contacting the bituminous feed with a flue gas from a combustion process.

[0076] The methods and systems may include providing (702) the bituminous feed with a bituminous feed water content outside of a target range of 2 - 25 weight (wt.) % or 4 - 8 wt. %.

[0077] The methods and systems may include selecting (704) a flue gas from a combustion process having a flue gas water content that is different than the bituminous feed water content. The combustion process may be local to a solvent extraction process, such as the solvent extraction discussed in the present disclosure. The flue gas may help control the water content within the bituminous feed. The use of flue gas for water content control may reduce the oxygen content of the bituminous feed. The oxygen content of the flue gas may be less than one of 3 vol %, 1 vol. % and 0.1 vol. %. The oxygen content of the flue gas may include any number within the preceding ranges. The flue gas may help control the temperature of the bituminous feed. The use of flue gas for water content control may increase a temperature of the bituminous feed. As described in the present disclosure, water or an aqueous solution may be used as an aqueous bridging liquid.

[0078] The flue gas used may be obtained from a combustion process that is in proximity to the solvent extraction process. For example, the flue gas may be from one of a power generation facility and a steam generation facility. The one of the power generation facility and the steam generation facility may be in proximity to a solvent extraction facility. The solvent extraction process may take place at the solvent extraction facility.

[0079] The flue gas may result from stoichiometric combustion of a fuel in order to minimize the amount of oxygen remaining in the flue gas. The stoichiometric combustion, of the combustion process, may be a substantially stoichiometric combustion. An example of a stoichiometric combustion process is described in WO 2012/003080 (Oelfke *et al.*). In Oelfke *et al.*, exhaust gas from a gas turbine system is cooled and then compressed to form a compressed recycle stream. The gas turbine system preferably has a combustion chamber configured to stoichiometrically combust a compressed oxidant and a fuel in the presence of a portion of the compressed recycle stream. The compressed recycle stream acts as a diluent configured to moderate the temperature of the discharge stream from the combustion chamber. The discharge stream is expanded to generate power, drive the compressor used to compress the recycle stream, and produce the exhaust gas. The remaining portion of the compressed recycle stream is the flue gas stream. The gas stream is directed to a CO₂ separator.

[0080] Flue gas produced from a combustion process, such as that described by Oelfke *et al.*, may be suitable for use in the present methods and systems because the flue gas may be comprised almost entirely of nitrogen and carbon dioxide gas.

[0081] Figures 3a and 3b compare a conventional natural gas combined cycle (NGCC) facility (Figure 3a) with a NGCC system combined with the compressed recycle stream (Figure 3b).

[0082] As shown in Figure 3a, the natural gas combined cycle system combines the Brayton Cycle with the Rankine Cycle. The Brayton Cycle is comprised at minimum with a compressor (302), a combustion chamber (304) and a turbine (306). Air (308) (in excess of a stoichiometric amount) is compressed by the compressor (302) and is then mixed with natural gas (310) in the combustion chamber (304). The hot discharge gas from the combustion process

is expanded in the turbine (306) to drive the compressor (302) and an electrical generator. The exhaust gas from the turbine (306) is then directed to a heat recovery steam generator (HRSG) (312) where the heat from the exhaust gas is used to boil the water in the Rankine Cycle. The steam produced in the HRSG is expanded in a steam gas turbine (SGT) (314) that is used to drive an additional electrical generator. As an example, the flue gas (316) from the HRSG (312) may comprise 4 vol. % CO₂, 8 vol. % H₂O, 74 vol. % N₂, 12 vol. % O₂, 2 vol. % other, and have a temperature of 140°C.

[0083] As shown in Figure 3b, the NGCC system with the compressed recycle stream uses similar equipment as the conventional NGCC facility but with the addition of a second HRSG system (312b) and a second compressor (302b). A stoichiometric amount of air (308b) is used. The second HRSG (312b) is used to further cool the exhaust gas. It may also cool the exhaust gas sufficiently to condense water (316). The cooled exhaust gas (318) is then compressed and a portion of the compressed recycle gas is used as a diluent stream (320) that is configured to moderate the temperature of the discharge stream from the combustion chamber (302b). The remaining portion of the compressed recycle gas is the flue gas stream (316b). As an example, the flue gas (316b) may comprise 10 vol. % CO₂ and 90 vol. % N₂, have a pressure of 19 bar, and have a temperature of 420°C. The flue gas produced from the NGCC system combined with the compressed recycle (Figure 3b) has a reduced amount of oxygen and water as compared to the flue gas of the NGCC system alone (Figure 3a).

[0084] The NGCC system with the compressed recycle stream produces a high temperature flue gas stream comprised of very small amounts of oxygen and water. The high temperature flue gas stream can be used to control the water content of a bituminous feed to solvent extraction. The high temperature flue gas stream may have a water content of less than 5 vol. % or less than 1 vol. %. The water content of the high temperature flue gas stream may be any number included within the preceding ranges.

[0085] The flue gas may be used to adjust other properties such as oxygen content and temperature. The flue gas may be used to decrease the oxygen content to below a flammable limit.

[0086] The flue gas may be used to increase the temperature of the bituminous feed to within a range of -20°C to 120°C or 0°C to 80°C. The temperature of the bituminous feed may be any number within or bounded by the preceding temperature ranges. The flue gas may be used to decrease the water content of the bituminous feed. The flue gas may flow countercurrent to the flow of the bituminous feed when the flue gas is used to decrease the water content of the bituminous feed.

[0087] The flue gas from the combustion process may directly come into contact with the bituminous feed or may be cooled in a heat exchanger prior to coming into contact with the bituminous feed if a cooler flue gas is desired in order to provide a resultant bituminous stream with a lower temperature.

[0088] The temperature of the flue gas may be greater than one of water dew point temperature of the flue gas and an acid dew point temperature of the flue gas. The temperature of the flue gas may be greater than one of the water dew point temperature of the acid dew point temperature after the flue gas contacts the bituminous feed. In this way, water or acid condensation after the flue gas contacts the bituminous feed can be mitigated.

[0089] The flue gas may be used to increase the water content of the bituminous feed. The flue gas from the combustion process can be directed to a mass exchanger in order to saturate or partially saturate the flue gas with water. The flue gas may be saturated or partially saturated with water before forming a resultant bituminous feed. The flue gas may be cooled in a heat exchanger prior to coming into contact with the bituminous feed. The temperature of the flue gas may be near or at its water dew point temperature before it contacts the bituminous feed, for instance within 10 % above or below the dew point. The temperature of flue gas may be above its acid dew point temperature. The flue gas may flow concurrent to the flow of the bituminous feed when the flue gas is used to increase the water content of the bituminous feed.

[0090] The methods and systems may comprise forming (706) a resultant bituminous feed with a resultant bituminous feed water content within the target range by contacting the bituminous feed and the flue gas. The resultant bituminous feed may be used as the previously described second bituminous feed. When the resultant bituminous feed is used as the previously

described second bituminous feed there may be another source for the second bituminous feed than those previously described.

[0091] The methods and systems may comprise passing (708) the resultant bituminous feed a solvent extraction process for extracting bitumen from the resultant bituminous feed. The solvent extraction process may include extracting bitumen from the resultant bituminous feed. The solvent extraction process may be a solvent extraction process described in the present disclosure.

[0092] The pretreatment of bituminous feed, by using a flue gas, has the advantage of controlling the amount of aqueous bridging liquid present in the oil sands slurry. Mined oil sands from the Athabasca region have a typical water content between 1 to 6 wt. %. At this level of water, additional aqueous bridging liquid is typically added to the oil sands slurry in order to optimize the solid agglomeration process. However, in some cases, the amount of water in the oil sands can be much greater than 6 wt. %. For example, the oil sands may be mined from a location of unusually high water saturation, or the oil sands after being mined may be exposed to precipitation that increases the water content of the oil sands. The bituminous feed may comprise a mixture of oil sands with a wet bituminous feed such as tailings from a water-based extraction process. Such a bituminous feed mixture may require additional drying prior to being directed to the solvent extraction process. This excess level of water can negatively impact the solvent extraction process. For example, when an excess amount of aqueous bridging liquid is present in the oil sands slurry, rapid growth of agglomerates can lead to a reduction in bitumen recovery owing to entrapment of the bitumen within the agglomerated solids. In some cases, the amount of aqueous bridging liquid can be sufficiently high that agglomerates fail to form and the solids turn into a paste with an extremely low permeability. This situation could lead to costly process delays and even shut-downs due to the failure of the solid-liquid separation process. Potential benefits of the pretreatment of the bituminous feed with a flue gas in order to decrease the water content of the bituminous feed may be improved bitumen recovery, improved process reliability, and/or less system down-time.

[0093] Figure 4 illustrates a pretreatment of a bituminous feed to decrease the water content of the bituminous feed. Figure 4 includes the system of Figure 3b up to the point of

producing the flue gas (316b). The flue gas (316b) is contacted with a bituminous feed (402) during feed pretreatment (404) to form a resultant bituminous feed (406) which is passed to solvent extraction (408). Waste flue gas (410) exits the feed pretreatment (404). The flue gas may be used to decrease a water content of the bituminous feed to less than 10 wt. % or less than 6 wt. %. The water content may be any number within the aforementioned ranges.

[0094] Pretreatment of a bituminous feed with a flue gas with a higher water content than the bituminous feed can provide the additional water needed for the agglomeration process. The latent heat provided by the condensing water from the flue gas can contribute to increasing the temperature of the bituminous feed to the level needed for the solvent extraction process.

[0095] Figure 5 illustrates pretreatment of a bituminous feed in order to increase the water content of the bituminous feed. Figure 5 includes the system of Figure 3b except that the flue gas used for pretreatment of the bituminous feed is taken prior to passing through HRSG (312b). The flue gas (500) is directed to a mass exchanger (501) in order to saturate or partially saturate the flue gas with water (503) to produce saturated flue gas (514). Saturated flue gas (514) is contacted with a bituminous feed (502) during feed pretreatment (504) to form a resultant bituminous feed (506) which is passed to solvent extraction (508). Waste flue gas (510) exits the feed pretreatment (504). The flue gas may be used to increase a water content of the bituminous feed to higher than 0.5 wt. % or higher than 2 wt. %. The water content may be any number within the aforementioned ranges.

[0096] The solvents described in the present disclosure may include low boiling point solvents such as low boiling point cycloalkanes, or a mixture of such cycloalkanes, which substantially dissolve asphaltenes. The solvent may comprise a paraffinic solvent in which the solvent to bitumen ratio, the temperature, the pressure or a combination thereof are maintained at levels to avoid or limit precipitation of asphaltenes.

[0097] While it is not necessary to use a low boiling point solvent, when used, there is the extra advantage that solvent recovery through an evaporative or distillation process proceeds at lower temperatures, and requires a lower energy consumption. When a low boiling point

solvent is selected, it may be one having a boiling point of less than 100°C. The boiling point of the solvent may be any number within the aforementioned range.

[0098] The solvent may comprise an organic solvent or a mixture of organic solvents. For example, the solvent may comprise a paraffinic solvent, an open chain aliphatic hydrocarbon, a cyclic aliphatic hydrocarbon, or a mixture thereof. Should a paraffinic solvent be utilized, it may comprise an alkane, a natural gas condensate, a distillate from a fractionation unit (or diluent cut), or a combination of these containing more than 40% small chain paraffins of 5 to 10 carbon atoms. This would be considered primarily a small chain (or short chain) paraffin mixture. Should an alkane be selected as the solvent, the alkane may comprise at least one of a normal alkane and an iso-alkane. The alkane may comprise at least one of heptane, iso-heptane, hexane, iso-hexane, pentane, and iso-pentane. Should a cyclic aliphatic hydrocarbon be selected as the solvent, it may comprise a cycloalkane of 4 to 9 carbon atoms. A mixture of C₄-C₉ cyclic and/or open chain aliphatic solvents would be appropriate. Exemplary cycloalkanes include at least one of cyclohexane and cyclopentane. If the solvent is selected as the distillate from a fractionation unit, it may for example be one having a final boiling point of less than 180°C. An exemplary upper limit of the final boiling point of the distillate may be less than 100°C. A mixture of C₄-C₁₀ cyclic and/or open chain aliphatic solvents would also be appropriate. For example, it can be a mixture of C₄-C₉ cyclic aliphatic hydrocarbons and paraffinic solvents where the percentage of the cyclic aliphatic hydrocarbons in the mixture is greater than 50%.

[0099] During solvent extraction with agglomeration, the bituminous feed may be mixed with an aqueous bridging liquid in order to agglomerate the solids within the bituminous feed and form an agglomerated slurry. The formed agglomerates within the agglomerated slurry may be sized on the order of 0.1-1.0 mm, or on the order of 0.1-0.3 mm. At least 80 wt. % of the formed agglomerates may be 0.1-1.0 mm, or 0.1 to 0.3 mm in size. The rate of agglomeration may be controlled by a balance between intensity of agitation within an agglomeration vessel, shear within the vessel which can be adjusted, for example, by changing the shape or size of the vessel, fines content of the slurry, aqueous bridging liquid addition, and

residence time of the agglomeration process. The agglomerated slurry may have a solids content of 20 to 70 wt. %.

[00100] The aqueous bridging liquid is a liquid with affinity for the solids particles in the bituminous feed, and which is immiscible in the solvent. Exemplary aqueous liquids may be water that accompanies the bituminous feed and/or recycled water from other aspects or steps of oil sands processing. The aqueous liquid need not be pure water, and may indeed be water containing one or more salts, a waste product from conventional aqueous oil sand extraction processes which may include additives, aqueous solution with a range of pH, or any other acceptable aqueous solution capable of adhering to solid particles in such a way that permits fines to adhere to each other. An exemplary aqueous bridging liquid is water. The aqueous bridging liquid may be added to the bituminous feed in a concentration of less than 20 wt. % of the slurry, less than 10 wt. % of the bituminous feed, between 1 wt. % and 20 wt. %, or between 1 wt. % and 10 wt. %. The aqueous bridging liquid may comprise fine particles (for instance less than 44 μm) suspended therein. The fine particles may serve as seed particles for the agglomeration process. The aqueous bridging liquid may comprise less than 40 wt.% solid fines, or have a solids content of 20 to 70 wt. %.

[00101] The agglomeration process may be assisted by some form of agitation. The form of agitation may be mixing, shaking, rolling, or another known suitable method. The agitation of the feed need only be severe enough and of sufficient duration to intimately contact the aqueous bridging liquid with the solids in the feed. Exemplary rolling type vessels include rod mills and tumblers. Exemplary mixing type vessels include mixing tanks, blenders, and attrition scrubbers. In the case of mixing type vessels, a sufficient amount of agitation is needed to keep the formed agglomerates in suspension. In rolling type vessels, the solids content of the feed may be greater than 40 wt. % so that compaction forces assist agglomerate formation. The agitation of the slurry has an impact on the growth of the agglomerates. In the case of mixing type vessels, the mixing power can be increased in order to limit the growth of agglomerates by attrition of said agglomerates. In the case of rolling type vessels the fill volume and rotation rate of the vessel can be adjusted in order to increase the compaction forces used in the comminution of agglomerates.

[00102] EXAMPLES**[00103] Example 1**

[00104] Approximately 1400 g of oil sands (bituminous feed) with a high water content (11.9 wt% water; water to solids ratio of 0.14) was mixed with a cyclohexane-bitumen mixture (extraction liquor) to form an approximately 60 wt% solids oil sands slurry with a solvent to bitumen ratio of 1 at 1500 rpm for 10 min. Additional cyclohexane (extraction liquor) was added to form an approximately 50 wt% solids oil sands slurry with solvent to bitumen ratio of 2, and mixed at 1500 rpm for additional 7 min. The agglomerates formed by the high initial water content were filtered from the bitumen extract, washed by cyclohexane and vacuumed-dried for 30 seconds on a Buchner funnel with a wedge wire screen (100 μ m slot) under vacuum. The residual bitumen in the washed agglomerates was used to calculate bitumen recovery. The bitumen recovery of processing this oil sands (bituminous feed) with high water content was 51%. The poor recovery was most likely due to entrapment of the bitumen within the oversized agglomerates (approximately 4.4% of agglomerates were larger than 8 mm) due to an excess amount of water in the oil sands slurry. This result indicated that excess water in this oil sands (bituminous feed) makes it unsuitable for the solvent extraction process.

[00105] Example 2

[00106] Approximately 350 g of oil sands (first bituminous feed) with a high water content (11.9 wt% water) was blended with 1050 g of oil sands (second bituminous feed) with a low water content (1.2 wt% water). The resultant third bituminous feed had a water to solids ratio of 0.045. The third bituminous feed was mixed with a cyclohexane-bitumen mixture (extraction liquor) to form an approximately 60 wt% solids oil sands slurry with a solvent to bitumen ratio of 1 at 1500 rpm for 10 min. Additional cyclohexane (extraction liquor) was added to form an approximately 50 wt% solids oil sands slurry with a solvent to bitumen ratio of 2, and mixed at 1500 rpm for additional 5 min. Water was added to achieve a water to solids ratio of 0.08 and the mixture was then mixed at 1500 rpm for additional 2 minutes. The agglomerates were filtered from the bitumen extract, washed by cyclohexane and vacuumed-dried for 30 seconds on a Buchner funnel with a wedge wire screen (100 μ m slot)

under vacuum. The residual bitumen in the washed agglomerates was used to calculate bitumen recovery. The bitumen recovery of processing this third bituminous feed was 90%. This result indicated that blending oils sands (bituminous feeds) with excess water (unsuitable for the solvent extraction process) with a low water content oil sands (bituminous feed) can eliminate or reduce the formation of over-sized agglomerates and thus maintain good bitumen recovery.

[00107] The scope of the claims should not be limited by particular embodiments set forth herein, but should be construed in a manner consistent with the specification as a whole.

CLAIMS:

1. A method for processing a bituminous feed, the method comprising:
 - a) providing the bituminous feed having a bituminous feed water content outside of a target range;
 - b) selecting a flue gas from a combustion process having a flue gas water content that is different than the bituminous feed water content;
 - c) forming a resultant bituminous feed with a resultant bituminous feed water content from 2 to 25 wt% by contacting the bituminous feed and the flue gas; and
 - d) passing the resultant bituminous feed to a solvent extraction process for extracting bitumen from the resultant bituminous feed.
2. The method of claim 1, wherein the flue gas is from one of a power generation facility and a steam generation facility.
3. The method of claim 1 or 2, wherein the combustion process comprises substantially stoichiometric combustion.
4. The method of any one of claims 1 to 3, wherein the combustion process uses a portion of a compressed recycle stream to dilute a discharge stream from a combustion chamber.
5. The method of any one of claims 1 to 4, wherein the oxygen content of the flue gas is less than one of 3 vol %, 1 vol. % and 0.1 vol. %.
6. The method of any one of claims 1 to 5, wherein the flue gas has a water content of less than one of 5 vol. % and 1 vol. %.
7. The method of any one of claims 1 to 6, further comprising at least one of (i) decreasing the water content of the bituminous feed to less than one of 10 wt. % and 6 wt. % by using the

flue gas and (ii) increasing the water content of the bituminous feed to higher than 2 wt % by using the flue gas.

8. The method of any one of claims 1 to 7, further comprising decreasing an oxygen content of the bituminous feed to below a flammable limit by using the flue gas.

9. The method of any one of claims 1 to 8, further comprising increasing a temperature of the bituminous feed to within a range of one of -20°C to 120°C and 0°C to 80°C by using the flue gas.

10. The method of any one of claims 1 to 8, further comprising cooling the flue gas in a heat exchanger prior to c).

11. The method of any one of claims 1 to 10, wherein the flue gas has a temperature greater than one of a water dew point temperature and an acid dew point temperature, prior to c).

12. The method of claim 7, further comprising one of counter-currently and concurrently flowing the flue gas and the bituminous feed.

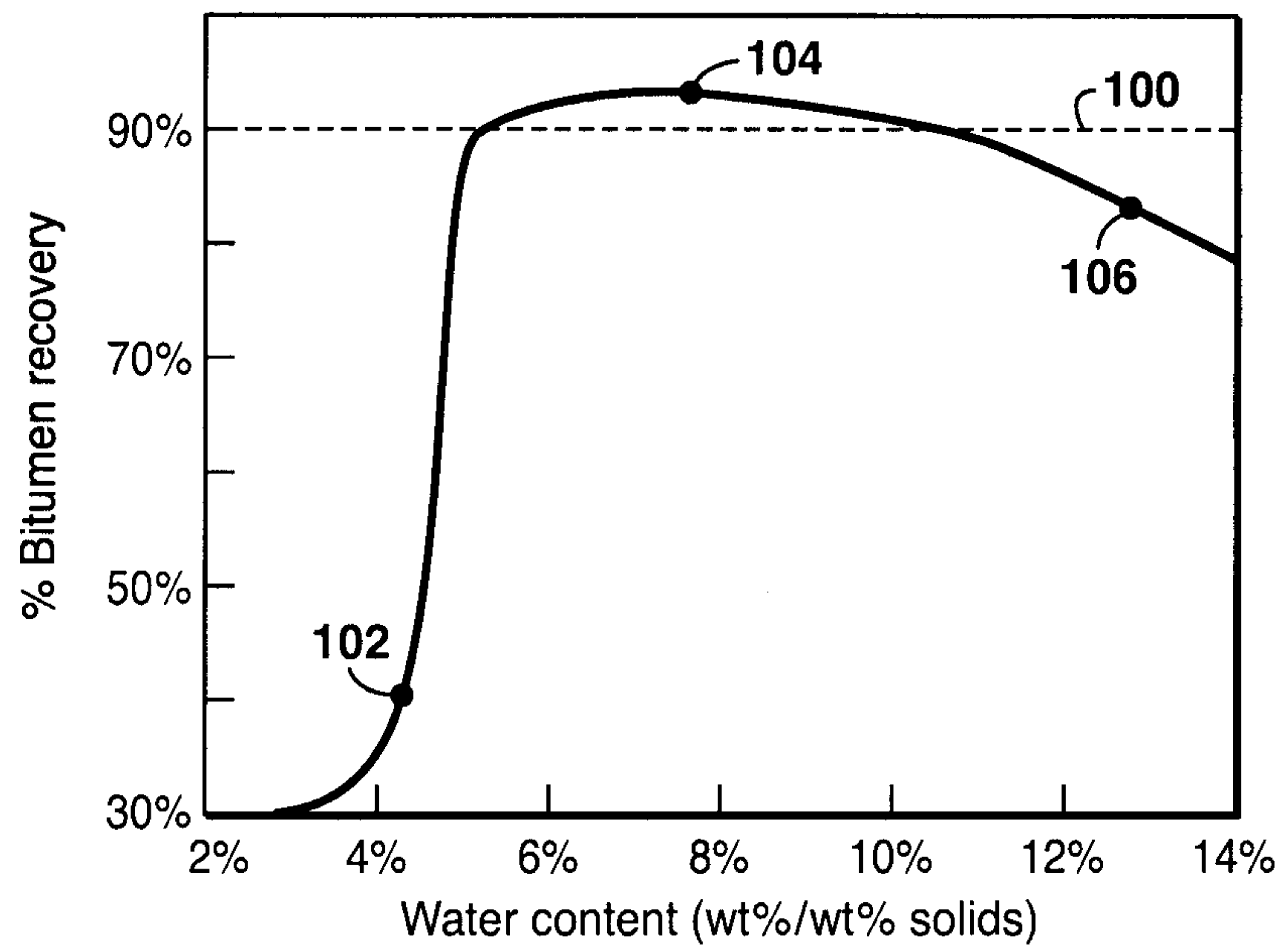
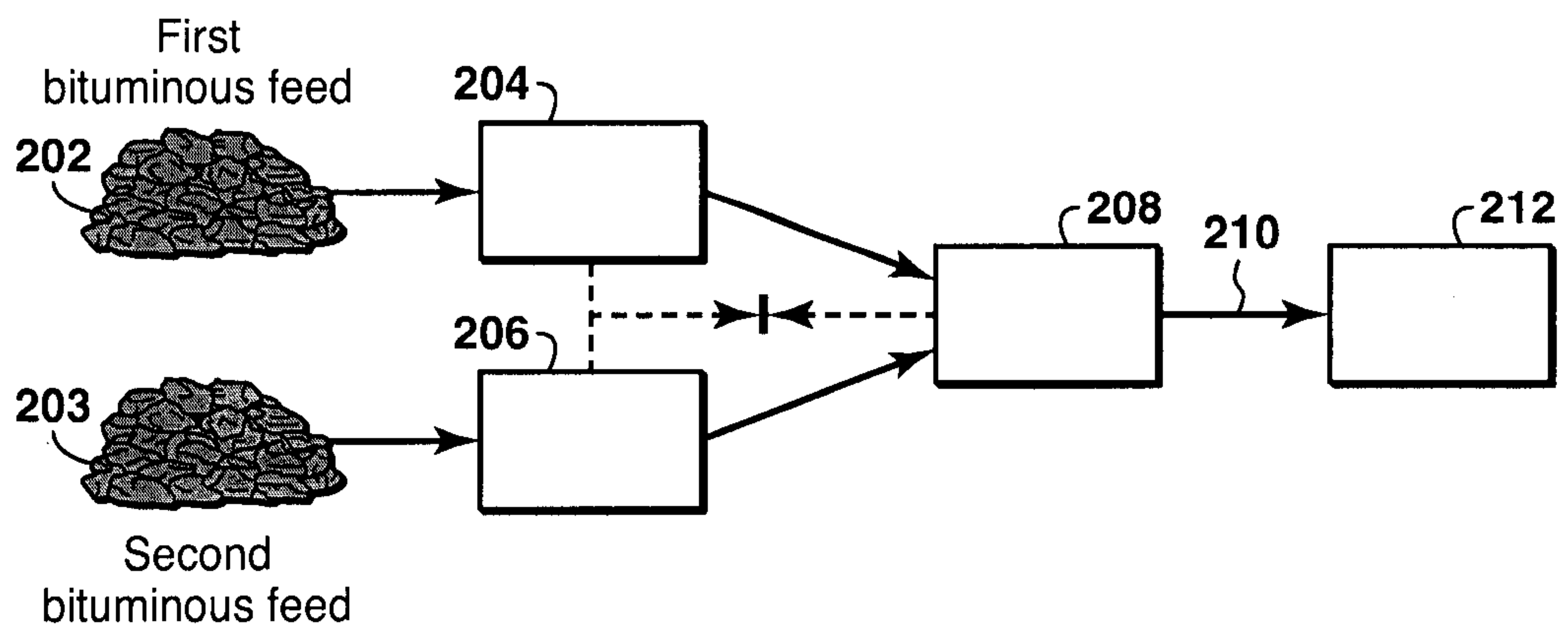
13. The method of any one of claims 1 to 7, further comprising saturating or partially saturating the flue gas with water prior to c).

14. The method of any one of claims 1 to 8, wherein the flue gas has a temperature within a range of 10% below to 10% above a water dew point temperature.

15. A method of any one of claims 1 to 14, further comprising extracting bitumen from the resultant bituminous feed in the solvent extraction process.

16. The method of any one of claims 1 to 15, further comprising using the resultant bituminous feed as a second bituminous feed.

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**FIG. 1****FIG. 2**

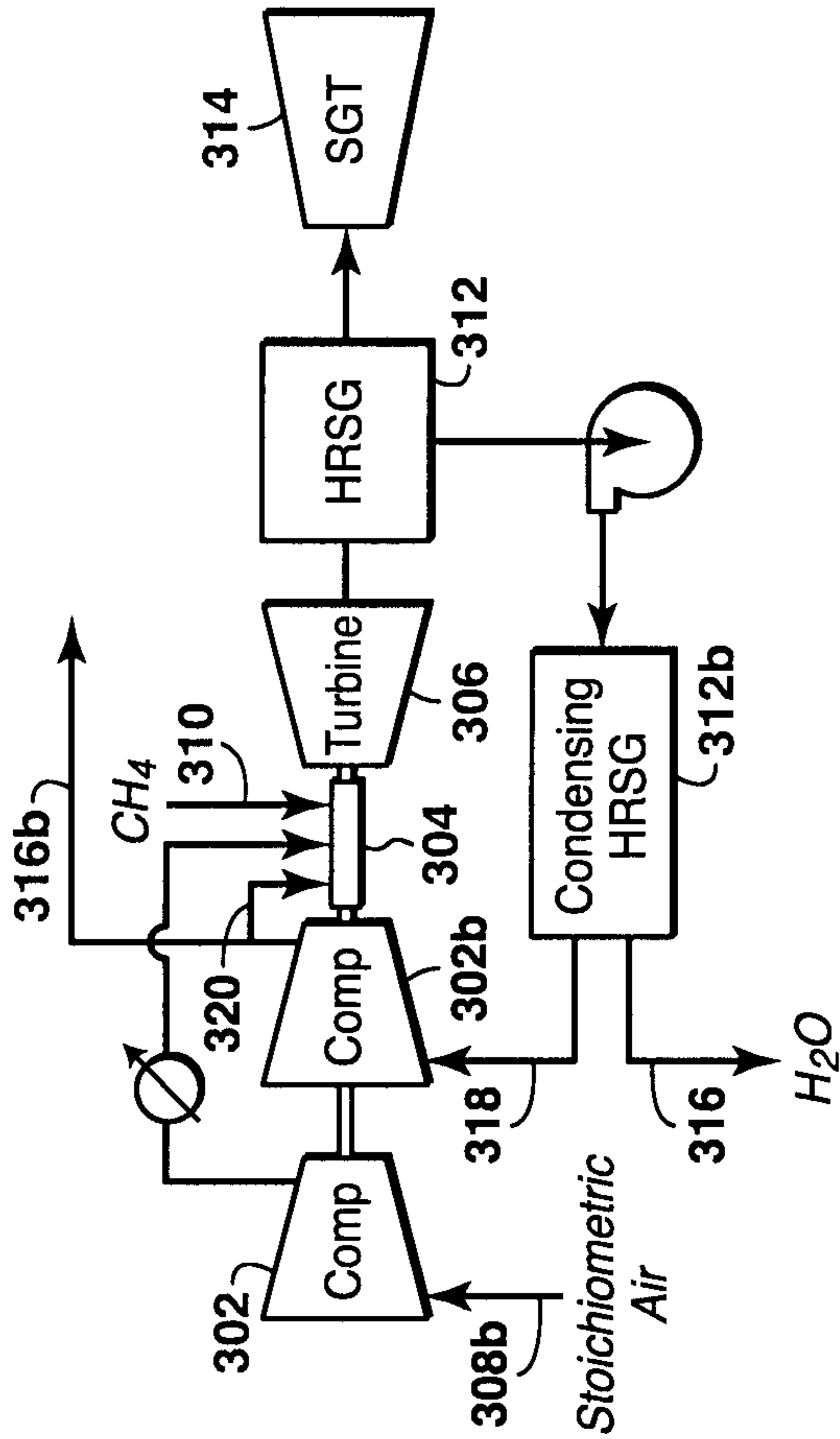


FIG. 3B

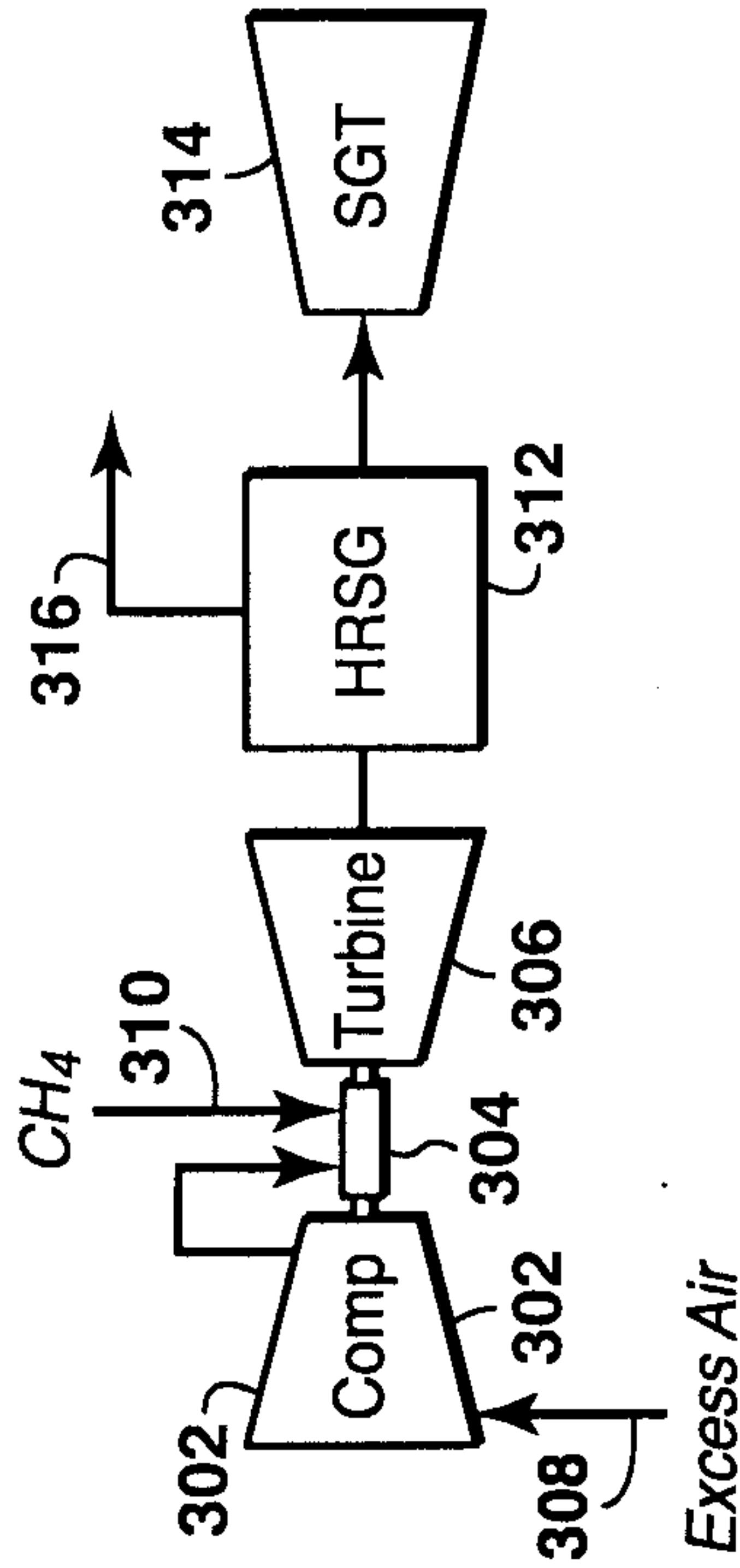


FIG. 3A

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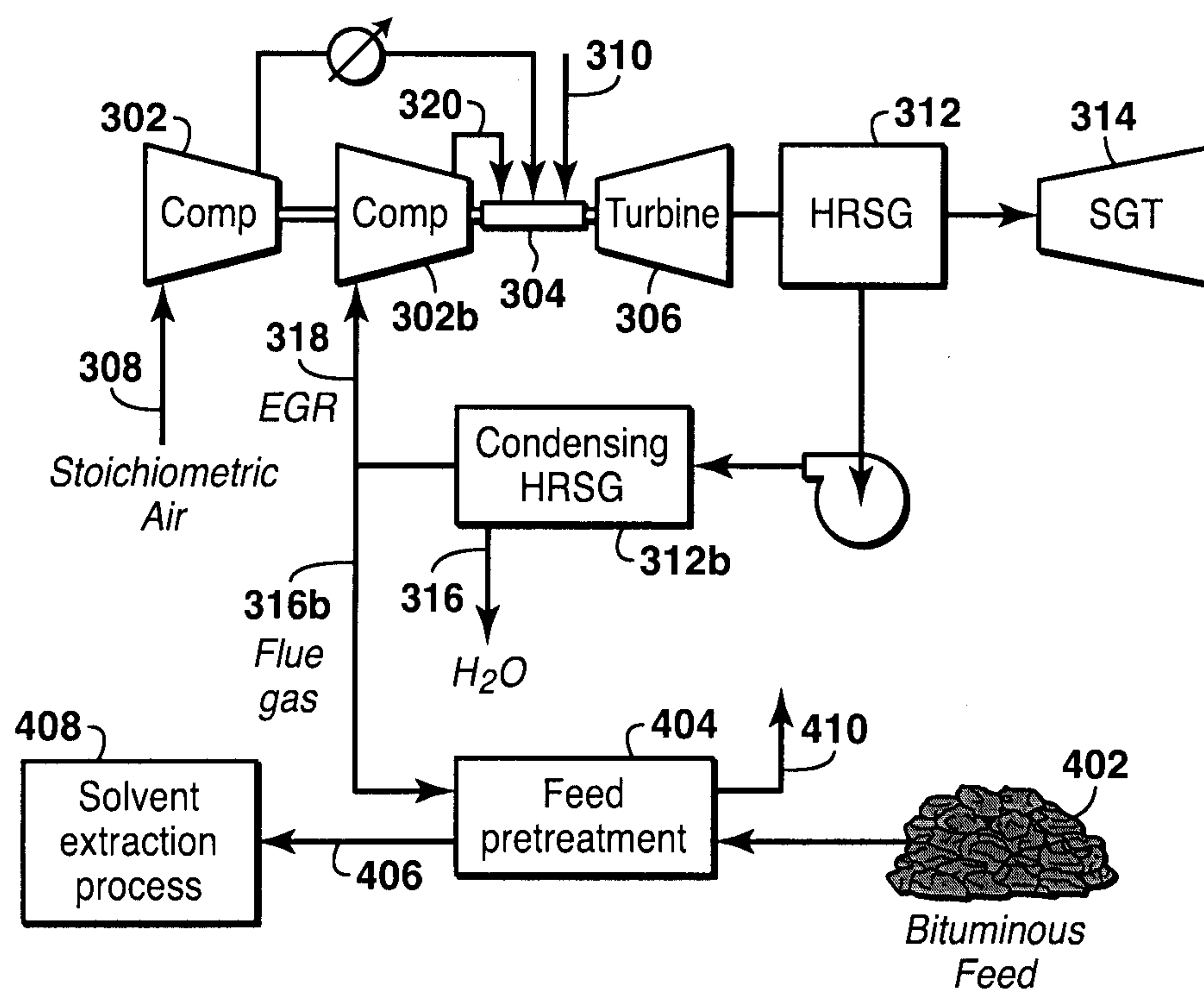


FIG. 4

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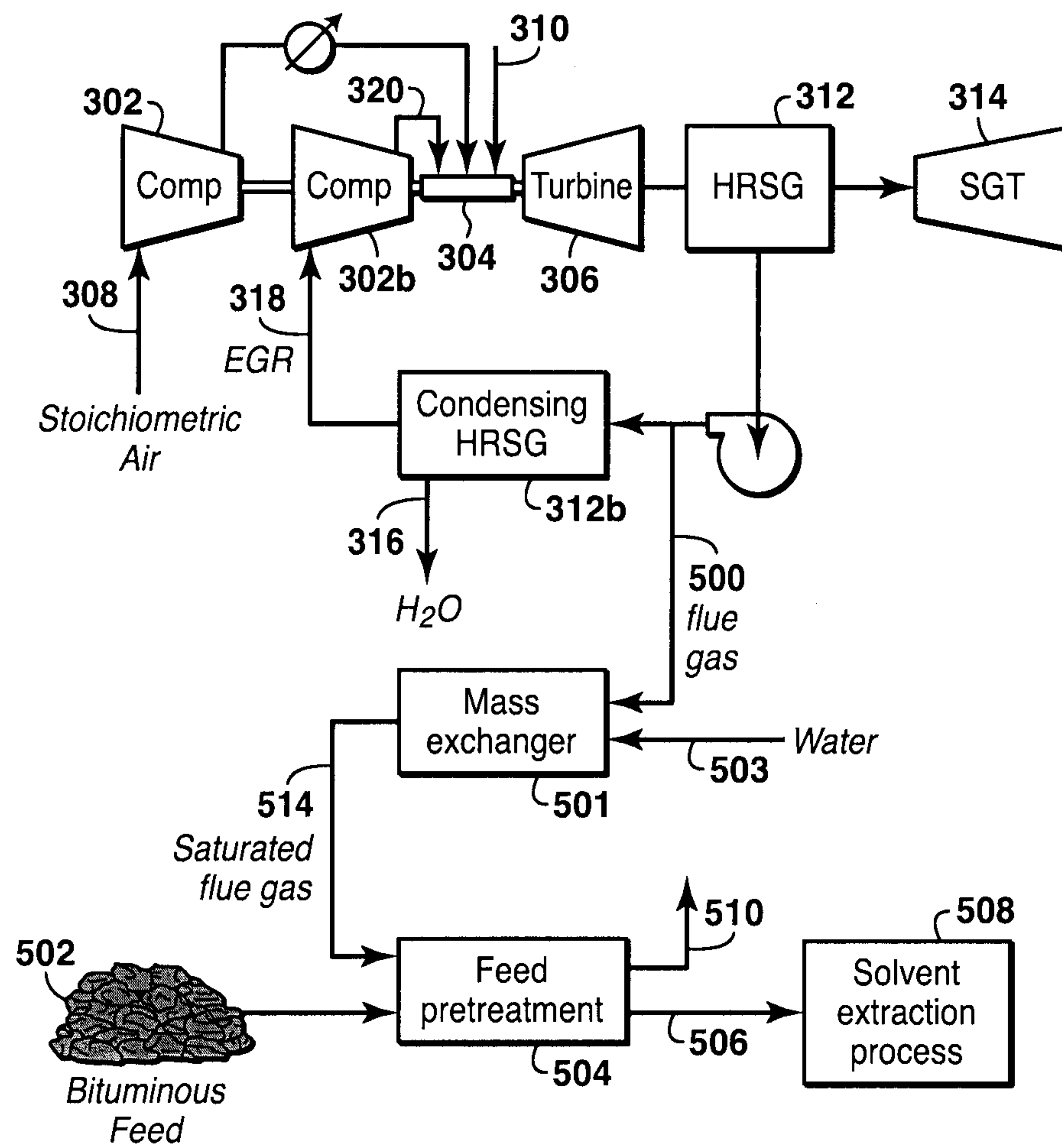
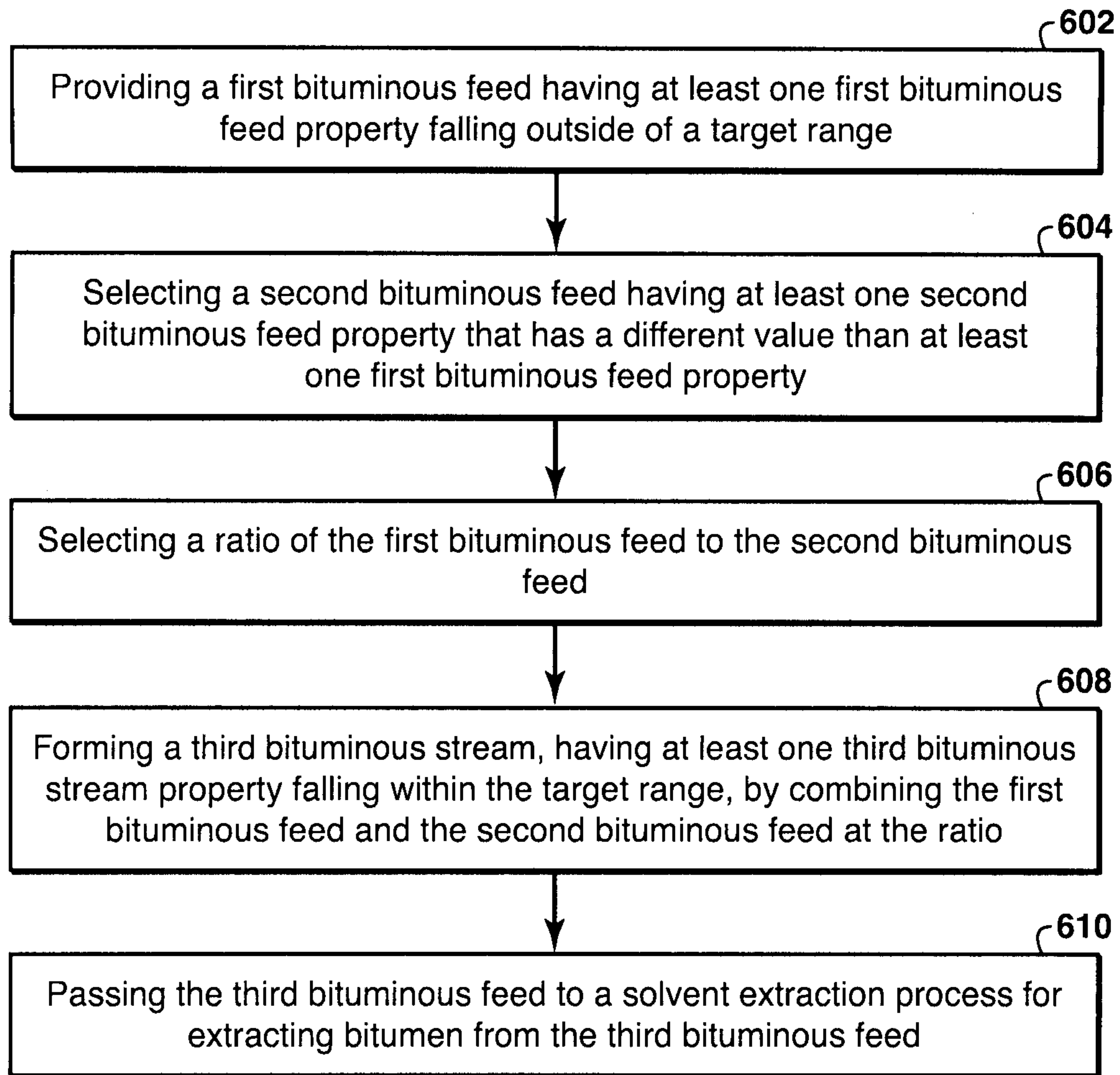
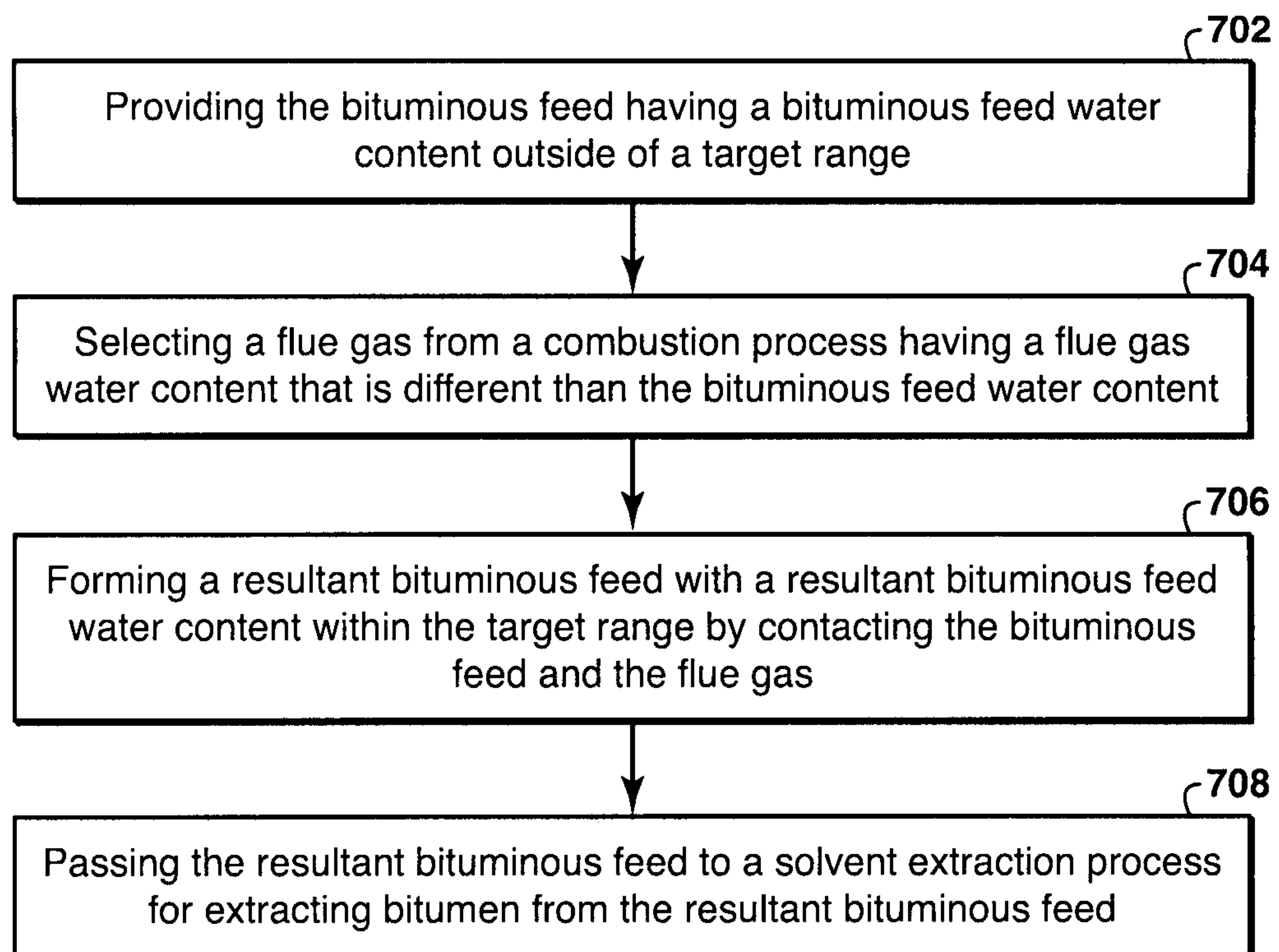


FIG. 5

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