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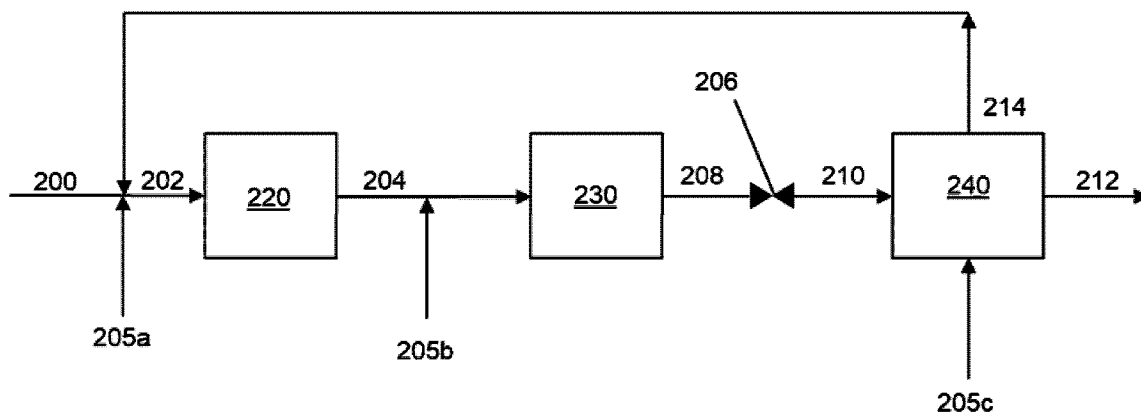
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(54) Titre : SYSTEMES ET METHODES D'HYDROVISCOREDUCTION D'HUILES LOURDES

(54) Title: SYSTEMS AND METHODS FOR HYDROVISBREAKING HEAVY OIL



(57) Abrégé/Abstract:

Provided herein is a hydrovisbreaking process that can be used to partially upgrade a heavy oil feedstock, thereby reducing the requirements for diluent during transportation. The hydrovisbreaking process involves adding hydrogen at multiple points in the process, which can facilitate dissolution of hydrogen in the heavy oil, while minimizing the quantity of high pressure hydrogen required. The heavy oil feedstock can optionally be mixed with dispersed catalysts for upgrading hydrocarbons.

ABSTRACT

Provided herein is a hydrovisbreaking process that can be used to partially upgrade a heavy oil feedstock, thereby reducing the requirements for diluent during transportation. The hydrovisbreaking process involves adding hydrogen at multiple points in the process, which can facilitate dissolution of hydrogen in the heavy oil, while minimizing the quantity of high pressure hydrogen required. The heavy oil feedstock can optionally be mixed with dispersed catalysts for upgrading hydrocarbons.

SYSTEMS AND METHODS FOR HYDROVISBREAKING HEAVY OIL

TECHNICAL FIELD

[0001] The following generally relates to thermal cracking of heavy hydrocarbons, particularly to methods and systems for hydrovisbreaking heavy oil.

BACKGROUND

[0002] Produced bitumen typically has a considerably high viscosity and can thus be difficult to transport via pipeline. To overcome this issue, the viscosity of bitumen can be decreased. For example, a conventional practice includes the dilution of bitumen using lighter hydrocarbon diluents, such as natural gas condensates. However, diluent used to meet pipeline specifications can be expensive, and can account for a meaningful portion of pipeline volumes, driving up transportation costs and limiting pipeline capacity. Partial upgrading of bitumen represents another approach to overcoming the issue of high bitumen viscosity.

[0003] Thermal cracking methods, such as visbreaking, could in principle be used to partially upgrade bitumen after oil recovery. However, due to the limited improvement in viscosity, density and generation of coke and unstable products, it can be difficult to use current visbreaking processes to convert heavy oil and bitumen into a product that meets pipeline specifications.

[0004] Hydrovisbreaking can be a non-catalytic or catalytic process that involves thermal cracking and hydrogenation of free radicals formed during cracking, thereby reducing impurities and ultimately resulting in higher quality products than those produced using conventional visbreaking. However, hydrovisbreaking is typically not widely used in refinery units due to the existence of more effective processes such as hydrocracking and fluid catalytic cracking, which can achieve the full conversion and upgrading often required by refineries.

[0005] It would be advantageous to develop an improved process for partially upgrading heavy oil.

SUMMARY

[0006] Provided herein is a hydrovisbreaking process that can be used to partially upgrade a heavy oil feedstock, thereby reducing the requirements for diluent during transportation. The following hydrovisbreaking process involves adding hydrogen in the presence or absence of catalysts at multiple points, which can facilitate dissolution of hydrogen in the heavy oil, while minimizing the quantity of high pressure hydrogen required.

[0007] In one aspect, provided herein is a method for hydrovisbreaking heavy oil, the method comprising: mixing a heavy oil feed with hydrogen to create a hydrogen enriched heavy oil feed; increasing the pressure of the hydrogen enriched heavy oil feed to create a pressurized hydrogen enriched heavy oil feed; heating the pressurized hydrogen enriched heavy oil feed to create a heated pressurized hydrogen enriched heavy oil feed; reducing the pressure of the heated pressurized hydrogen enriched heavy oil feed to create a vessel feed stream; and introducing the vessel feed stream into a hydrovisbreaking vessel having additional hydrogen fed therethrough, to convert the vessel feed stream to a partially hydrovisbroken product.

[0008] In another aspect, there is provided a system for hydrovisbreaking heavy oil, comprising: a heavy oil feed configured to mix with hydrogen to create a hydrogen enriched heavy oil feed; a first device to increase the pressure of the hydrogen enriched heavy oil feed to create a pressurized hydrogen enriched heavy oil feed; a heater to heat the pressurized hydrogen enriched heavy oil feed to create a heated pressurized hydrogen enriched heavy oil feed; a second device to reduce the pressure of the heated pressurized hydrogen enriched heavy oil feed to create a vessel feed stream; and a hydrovisbreaking vessel into which the vessel feed stream is introduced, the hydrovisbreaking vessel having additional hydrogen fed therethrough to convert the vessel feed stream to a partially hydrovisbroken product.

[0009] In an implementation, the method can include mixing the pressurized hydrogen enriched heavy oil feed with hydrogen prior to heating the pressurized hydrogen enriched heavy oil feed.

[0010] In an implementation, the hydrovisbreaking vessel can be a soaker vessel.

[0011] In an implementation, the pressure of the pre-heated pressurized hydrogen enriched heavy oil feed is reduced using one or more nozzles. The hydrogen enriched heavy oil feed can also be subjected to hydrodynamic cavitation.

[0012] In an implementation, the vessel feed stream can be sparged with hydrogen in the hydrovisbreaking vessel. The heavy oil feed can also mixed with dispersed catalysts for upgrading hydrocarbons.

[0013] In an implementation, the method can include recycling hydrogen from the hydrovisbreaking vessel to create a hydrogen recycle stream. The hydrogen mixed with the heavy oil feed can be provided at least in part from the hydrogen recycle stream.

[0014] In an implementation, the hydrogen mixed with the heavy oil feed can be obtained at least in part from a hydrogen recycle stream.

[0015] In an implementation, the method can include providing the partially hydrovisbroken product to a pipeline for transport.

[0016] In an implementation, the pressure of the hydrogen enriched heavy oil feed can be increased using at least one pump. The pressure of the hydrogen enriched heavy oil feed can also be increased by feeding through a low pressure pump followed by a high pressure pump. The method can include feeding an output of the low pressure pump to a low temperature furnace to create a pre-heated hydrogen enriched heavy oil stream, which is fed to the high pressure pump followed by a high temperature furnace, to create the heated pressurized hydrogen enriched heavy oil stream. The output of the low pressure pump can be mixed with hydrogen. The method can also include mixing the pre-heated hydrogen enriched heavy oil stream with hydrogen following the high pressure pump.

[0017] In an implementation, the method can include mixing the heavy oil feed with the dispersed catalysts using a mixer.

[0018] In an implementation, the vessel feed stream can enter a high pressure visbreaking vessel to create an intermediate hydrovisbroken product, which enters a low

pressure visbreaking vessel to create the partially hydrovisbroken product. The pressure of the intermediate hydrovisbroken product can also be reduced. The pressure of the intermediate hydrovisbroken product can be reduced using a valve.

[0019] In an implementation, a hydrogen feed stream can be directed into the high pressure soaker vessel. Excess hydrogen and any present non-condensable gases can exit the high pressure soaker vessel to create an overhead stream.

[0020] In an implementation, the method can include feeding a light stream exiting the low pressure soaker vessel to an olefin saturation process to saturate olefins in the light stream. The olefin saturation process can include a hydro-treater. The method can include combining light hydrocarbons from the olefin saturation process with the partially hydrovisbroken product to create a partially upgraded product stream.

[0021] In an implementation, the method can include recycling excess hydrogen from the olefin saturation process.

[0022] In an implementation, the hydrovisbreaking vessel can be a coil visbreaking vessel.

[0023] In an implementation, the added hydrogen can include both a hydrogen feed stream and a recycled hydrogen stream.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] Embodiments will now be described with reference to the appended drawings wherein:

[0025] FIG. 1 is a flow diagram illustrating a general hydrovisbreaking process having staged hydrogen addition.

[0026] FIG. 2 is a flow diagram illustrating another hydrovisbreaking process having staged hydrogen addition.

DETAILED DESCRIPTION

[0027] In hydrovisbreaking processes, an important parameter in determining the required level of hydrogen dissolution in the heavy oil feedstock is the feedstock viscosity. A more viscous feedstock generally needs to undergo more cracking

reactions than a relatively less viscous feedstock to arrive at the same target viscosity (e.g., a viscosity required for pipeline transport). Dissolved hydrogen can stabilize the free radicals produced by these cracking reactions, and thus more viscous feedstocks tend to require more dissolved hydrogen.

[0028] Hydrovisbreaking processes typically involve adding hydrogen to a heavy oil feedstock at a single stage in the process and/or upstream of the hydrovisbreaking reactor. In such processes, it is often the case that the required level of hydrogen dissolution in the heavy oil is achieved in a relatively short time. This can necessitate mixing the heavy oil with considerable quantities of high pressure hydrogen, requiring expensive equipment such as gas injection pumps or compressors.

[0029] Since the staged addition of hydrogen (i.e., addition at multiple points in the process) as described in greater detail below can provide more time for hydrogen to be dissolved, the required level of hydrogen dissolution can be achieved using less expensive hydrogen mixing methods. For example, some combination of low and high pressure hydrogen addition can be implemented that achieves the required level of dissolution and conversion while decreasing capital and/or operating costs. Additionally, the process provided herein can involve the addition of hydrogen directly to a hydrovisbreaking vessel, such as a soaker vessel or a coil visbreaking vessel. Since the majority of thermal cracking typically occurs in hydrovisbreaking vessels, it is expected that providing hydrogen directly to these vessels can further enhance hydrovisbreaking performance (e.g., to improve conversion, reduce coke formation, etc.).

[0030] The term “heavy oil” as used herein refers to petroleum materials having a viscosity considered too high for pipeline transportation at ambient temperature. Thus, this term can refer to, for example, bitumen, heavy oil, or de-asphalted oil (“DAO”). In an example implementation, the viscosity of bitumen fed into the process described herein can be approximately 6-14 API, the viscosity of heavy oil can be approximately 14-22 API, and for the viscosity for DAO can be approximately 10-16 API.

[0031] FIG. 1 is a flow diagram illustrating a method for hydrovisbreaking a heavy oil feed 200. The heavy oil feed 200, with or without dispersed catalysts (some of which

are listed below in describing FIG. 2), can be mixed with a hydrogen stream 205a and/or a hydrogen recycle stream 214, resulting in a hydrogen enriched heavy oil feed 202, wherein hydrogen can be dissolved and/or dispersed in the heavy oil. The hydrogen enriched heavy oil feed 202 can enter a pump 220 which can increase the pressure of the hydrogen enriched heavy oil feed 202, creating a pressurized hydrogen enriched heavy oil feed 204. The pressurized hydrogen enriched heavy oil feed 204 can be mixed with another hydrogen stream 205b to increase the hydrogen content of the pressurized hydrogen enriched heavy oil feed 204. The pressurized hydrogen enriched heavy oil feed 204 can subsequently enter a heater 230 to create a pre-heated pressurized hydrogen enriched heavy oil feed 208 being at a target temperature (or within a target temperature range). The pre-heated feed 208 can be subjected to a pressure drop by passing through a valve 206, thereby creating a soaker vessel feed stream 210 being at a target pressure. The soaker vessel feed stream 210 can be fed into a soaker vessel 240 wherein the heavy oil in the soaker vessel feed stream 210 can be hydrovisbroken (i.e., thermally cracked in the presence of hydrogen) to create a hydrovisbroken oil product 212 that is pipeline ready, or nearly pipeline ready with respect to viscosity. Another hydrogen stream 205c can be fed into the soaker vessel 240, wherein the hydrogen can be sparged and mixed with the heavy oil in the soaker vessel. Optionally, olefins generated during cracking can be reduced in a hydrotreating step (not shown). The soaker vessel 240 can be, for example, a horizontal soaker vessel configured for a residence time of from approximately 5 min to approximately 90 min. The soaker vessel 240 can be oriented horizontally or vertically.

[0032] FIG. 2 is a block flow diagram illustrating another implementation of the process for hydrovisbreaking a heavy oil feed 2. The heavy oil feed 2 can enter a mixer 100, where the heavy oil 2 can be mixed with a recycled hydrogen stream 30 and/or a hydrogen feed stream 5a to create a hydrogen enriched heavy oil stream 4. The hydrogen enriched heavy oil stream 4 can optionally have one or more upgrading catalysts 7 dispersed therein using another mixer 102. Such catalysts 7 can include one or more known dispersed catalysts for upgrading hydrocarbons, such as, for example, unsupported transition metal catalysts. Known unsupported transition metal

catalysts can include, but are not limited to, molybdenum-, nickel-, iron-, tungsten-, cobalt- and vanadium-based catalysts. For example, water soluble catalysts such as ammonium, sodium molybdate, or cobalt sulfate; or oil soluble catalysts such as molybdenum octoate or cobalt octoate can be used. A pre-determined amount of the catalyst(s) 7 can be added to the hydrogen enriched heavy oil stream 4, and the pre-determined amount can be based on, e.g., the maximum permissible solids content for pipeline transportation.

[0033] The hydrogen enriched heavy oil stream 4 can be pumped through a low-pressure pump 104 to increase the pressure of the stream 4, resulting in a pressurized hydrogen enriched heavy oil stream 8 at a pressure of from about 2MPa to about 10MPa. A hydrogen feed stream 5b can optionally mix with the pressurized hydrogen enriched heavy oil stream 8 in another mixer 106. Subsequently, the pressurized hydrogen enriched heavy oil stream 8 can enter a low temperature furnace 108 to create a pre-heated hydrogen enriched heavy oil stream 12. The pre-heated hydrogen enriched heavy oil stream 12 can optionally mix with another hydrogen feed stream 5c in another mixer 110 prior to entering a high pressure pump 112. The high pressure pump 112 can further increase the pressure of the pre-heated hydrogen enriched heavy oil stream 12, creating a high pressure hydrogen enriched heavy oil stream 16 which can be at a pressure of, for example, about 15MPa or higher. The high pressure hydrogen enriched heavy oil stream 16 can optionally be mixed with another hydrogen feed stream 5d in another mixer 114, and then fed to a high temperature furnace 116. The high temperature furnace 116 can bring the high pressure hydrogen enriched heavy oil stream 16 up to a target temperature of, for example, about 350°C to about 500°C to create a high temperature/pressure hydrogen enriched heavy oil stream 20. The high temperature/pressure hydrogen enriched heavy oil stream 20 can pass through a valve 118 which can be used to subject the stream 20 to a pressure drop, creating a high pressure soaker feed stream 22 having a temperature of, for example, about 350°C to about 500°C, and a pressure of, for example, about 5 MPa to about 20 MPa.

[0034] The high pressure soaker feed stream 22 can enter a high pressure soaker vessel 120, wherein thermal cracking in the presence of hydrogen (dissolved and undissolved in the stream 22) can occur. Another hydrogen feed stream 5e can be directed into the high pressure soaker vessel 120, thereby ensuring an excess of hydrogen is present in the soaker 120 to reduce or eliminate generation of unwanted side products and improve residue conversion. An overhead stream 9 comprising excess hydrogen and other non-condensable gases can exit the high pressure soaker vessel 120. An intermediate hydrovisbroken product 24 can exit the high pressure soaker vessel 120 and then pass through a valve 122 which can subject the intermediate hydrovisbroken product 24 to a pressure drop, resulting in a low pressure soaker feed stream 26.

[0035] Along with the overhead stream 9 and/or another hydrogen feed stream 5f, the low pressure soaker feed stream 26, which can be at a pressure of, for example, from about 0.1MPa to about 5MPa, can be fed into a low pressure soaker vessel 124. In the low pressure soaker vessel 124, thermal cracking of heavy oil in the low pressure soaker feed stream 26 can take place in the presence of excess hydrogen to create a hydrovisbroken product stream 25 having increased API gravity. A light stream 28 can exit the low pressure soaker vessel 124, and can optionally be fed to an olefin saturation process or apparatus, e.g., a hydro-treater 126, to saturate olefins in the light stream 28. Saturated light hydrocarbons 32 can exit the hydro-treater 126 and be combined with the hydrovisbroken product stream 25 to create a partially upgraded product stream 34 that is pipeline ready or nearly pipeline ready with respect to viscosity (e.g., < 400 cSt), olefin concentration (e.g., < 1%), and solids content (e.g., < 0.5%). Excess hydrogen from the hydro-treater 126 can be recycled as the recycled hydrogen stream 30.

[0036] The following Table 1 illustrates operational values that can be expected in a continuous reactor, compared to a commercial thermal cracking process having a known set of performance values.

Test Type	Unit	Batch 1	Batch 2	Batch 3	Batch 4	Commercial Thermal Cracking
Temperature	°C	430	430	430	415	415
Pressure-step1	MPa (gauge)	5	5	5	5	0
Pressure-step2	MPa (gauge)	15	15	15	10	18
Gas phase		N2	H2	H2	N2	No gas
Catalyst	Mo ppm	0	0	200	0	0
API		12.7	14.4	14.7	9.7	8.9
Viscosity reduction	%	99.0%	99.8%	99.9%	98.0%	81.7%
Coke make	wt. %	4.3	1.07	0.1	0.01	0
Yield	vol %	91%	100%	102%	101%	101%
H2 consumption	scft H2/bbl	NA	171	244	NA	NA

Table 1: Example Batch Reactor Data

[0037] It can be appreciated that the valves 118 and 122 can be, for example, nozzles used for inducing hydrodynamic cavitation of heavy oil to further reduce the viscosity of the heavy oil. It can also be appreciated that some degree of thermal cracking in the presence of hydrogen (i.e., hydrovisbreaking) can occur in the furnaces 108 and 116.

[0038] It can also be appreciated that coil visbreaking vessels, in which residence times are relatively short and operating temperatures are high, could be implemented in the above described hydrovisbreaking processes instead of soaker vessels. As noted above, hydrogen addition directly to a coil visbreaking vessel can also improve hydrovisbreaking performance since, similar to soaker visbreaking, the majority of the cracking reactions can occur in the coil visbreaking vessel.

[0039] For simplicity and clarity of illustration, where considered appropriate, reference numerals may be repeated among the figures to indicate corresponding or analogous elements. In addition, numerous specific details are set forth in order to provide a thorough understanding of the examples described herein. However, it will be understood by those of ordinary skill in the art that the examples described herein may be practiced without these specific details. In other instances, well-known methods, procedures and components have not been described in detail so as not to obscure the

examples described herein. Also, the description is not to be considered as limiting the scope of the examples described herein.

[0040] The examples and corresponding diagrams used herein are for illustrative purposes only. Different configurations and terminology can be used without departing from the principles expressed herein. For instance, components and modules can be added, deleted, modified, or arranged with differing connections without departing from these principles.

[0041] The steps or operations in the flow charts and diagrams described herein are just for example. There may be many variations to these steps or operations without departing from the principles discussed above. For instance, the steps may be performed in a differing order, or steps may be added, deleted, or modified.

[0042] Although the above principles have been described with reference to certain specific examples, various modifications thereof will be apparent to those skilled in the art as outlined in the appended claims.

Claims:

1. A method for hydrovisbreaking heavy oil, the method comprising:
mixing a heavy oil feed with hydrogen to create a hydrogen enriched heavy oil feed;
increasing the pressure of the hydrogen enriched heavy oil feed to create a pressurized hydrogen enriched heavy oil feed;
heating the pressurized hydrogen enriched heavy oil feed to create a heated pressurized hydrogen enriched heavy oil feed;
reducing the pressure of the heated pressurized hydrogen enriched heavy oil feed to create a vessel feed stream; and
introducing the vessel feed stream into a hydrovisbreaking vessel having additional hydrogen fed therethrough, to convert the vessel feed stream to a partially hydrovisbroken product.
2. The method of claim 1, further comprising mixing the pressurized hydrogen enriched heavy oil feed with hydrogen prior to heating the pressurized hydrogen enriched heavy oil feed.
3. The method of claim 1 or claim 2, wherein the hydrovisbreaking vessel is a soaker vessel.
4. The method of any one of claims 1 to 3, wherein the pressure of the pre-heated pressurized hydrogen enriched heavy oil feed is reduced using one or more nozzles.
5. The method of claim 4, wherein the hydrogen enriched heavy oil feed is subjected to hydrodynamic cavitation.
6. The method of any one of claims 1 to 5, wherein the vessel feed stream is sparged with hydrogen in the hydrovisbreaking vessel.

7. The method of any one of claims 1 to 6, wherein the heavy oil feed is mixed with dispersed catalysts for upgrading hydrocarbons.
8. The method of any one of claims 1 to 7, further comprising recycling hydrogen from the hydrovisbreaking vessel to create a hydrogen recycle stream.
9. The method of claim 8, wherein the hydrogen mixed with the heavy oil feed is provided at least in part from the hydrogen recycle stream.
10. The method of any one of claims 1 to 8, wherein the hydrogen mixed with the heavy oil feed is obtained at least in part from a hydrogen recycle stream.
11. The method of any one of claims 1 to 10, further comprising providing the partially hydrovisbroken product to a pipeline for transport.
12. The method of any one of claims 1 to 11, wherein the pressure of the hydrogen enriched heavy oil feed is increased using at least one pump.
13. The method of claim 12, wherein the pressure of the hydrogen enriched heavy oil feed is increased by feeding through a low pressure pump followed by a high pressure pump.
14. The method of claim 13, further comprising feeding an output of the low pressure pump to a low temperature furnace to create a pre-heated hydrogen enriched heavy oil stream, which is fed to the high pressure pump followed by a high temperature furnace, to create the heated pressurized hydrogen enriched heavy oil stream.
15. The method of claim 14, further comprising mixing the output of the low pressure pump with hydrogen.
16. The method of claim 14 or claim 15, further comprising mixing the pre-heated hydrogen enriched heavy oil stream with hydrogen following the high pressure pump.

17. The method of any one of claims 7 to 16, further comprising mixing the heavy oil feed with the dispersed catalysts using a mixer.

18. The method of any one of claims 1 to 17, wherein the vessel feed stream enters a high pressure visbreaking vessel to create an intermediate hydrovisbroken product, which enters a low pressure visbreaking vessel to create the partially hydrovisbroken product.

19. The method of claim 18, further comprising reducing the pressure of the intermediate hydrovisbroken product.

20. The method of claim 19, wherein the pressure of the intermediate hydrovisbroken product is reduced using a valve.

21. The method of any one of claims 18 to 20, wherein a hydrogen feed stream is directed into the high pressure soaker vessel.

22. The method of claim 21, wherein excess hydrogen and any present non-condensable gases exit the high pressure soaker vessel to create an overhead stream.

23. The method of any one of claims 18 to 22, further comprising feeding a light stream exiting the low pressure soaker vessel to an olefin saturation process to saturate olefins in the light stream.

24. The method of claim 23, wherein the olefin saturation process comprises a hydro-treater.

25. The method of claim 23 or claim 24, further comprising combining light hydrocarbons from the olefin saturation process with the partially hydrovisbroken product to create a partially upgraded product stream.

26. The method of any one of claims 23 to 25, further comprising recycling excess hydrogen from the olefin saturation process.
27. The method of any one of claims 1 to 2 or 4 to 26, wherein the hydrovisbreaking vessel is a coil visbreaking vessel.
28. The method of any one of claims 1 to 27, wherein the added hydrogen comprises both a hydrogen feed stream and a recycled hydrogen stream.
29. A system for hydrovisbreaking heavy oil, comprising:
a heavy oil feed configured to mix with hydrogen to create a hydrogen enriched heavy oil feed;
a first device to increase the pressure of the hydrogen enriched heavy oil feed to create a pressurized hydrogen enriched heavy oil feed;
a heater to heat the pressurized hydrogen enriched heavy oil feed to create a heated pressurized hydrogen enriched heavy oil feed;
a second device to reduce the pressure of the heated pressurized hydrogen enriched heavy oil feed to create a vessel feed stream; and
a hydrovisbreaking vessel into which the vessel feed stream is introduced, the hydrovisbreaking vessel having additional hydrogen fed therethrough to convert the vessel feed stream to a partially hydrovisbroken product.
30. The system of claim 29, further configured to mix the pressurized hydrogen enriched heavy oil feed with hydrogen prior to heating the pressurized hydrogen enriched heavy oil feed.
31. The system of claim 29 or claim 30, wherein the hydrovisbreaking vessel is a soaker vessel.

32. The system of any one of claims 29 to 31, wherein the second device comprises one or more nozzles.

33. The system of claim 32, wherein the hydrogen enriched heavy oil feed is subjected to hydrodynamic cavitation.

34. The system of any one of claims 29 to 33, wherein the vessel feed stream is sparged with hydrogen in the hydrovisbreaking vessel.

35. The system of any one of claims 29 to 34, further configured to mix the heavy oil feed with dispersed catalysts for upgrading hydrocarbons.

36. The system of any one of claims 29 to 35, further comprising a hydrogen recycle stream for recycling hydrogen from the hydrovisbreaking vessel.

37. The system of claim 36, wherein the hydrogen mixed with the heavy oil feed is provided at least in part from the hydrogen recycle stream.

38. The system of any one of claims 29 to 37, wherein the hydrogen mixed with the heavy oil feed is obtained at least in part from a hydrogen recycle stream.

39. The system of any one of claims 29 to 38, further comprising a connection to provide the partially hydrovisbroken product to a pipeline for transport.

40. The system of any one of claims 29 to 39, wherein the first device comprises at least one pump.

41. The system of claim 40, wherein the pressure of the hydrogen enriched heavy oil feed is increased by feeding through a low pressure pump followed by a high pressure pump.

42. The system of claim 41, configured to feed an output of the low pressure pump to a low temperature furnace to create a pre-heated hydrogen enriched heavy oil stream, which is fed to the high pressure pump followed by a high temperature furnace, to create the heated pressurized hydrogen enriched heavy oil stream.
43. The system of claim 42, further configured to mix the output of the low pressure pump with hydrogen.
44. The system of claim 42 or claim 43, further configured to mix the pre-heated hydrogen enriched heavy oil stream with hydrogen following the high pressure pump.
45. The system of any one of claims 35 to 44, further configured to mix the heavy oil feed with the dispersed catalysts.
46. The system of any one of claims 29 to 45, wherein the vessel feed stream enters a high pressure visbreaking vessel to create an intermediate hydrovisbroken product, which enters a low pressure visbreaking vessel to create the partially hydrovisbroken product.
47. The system of claim 46, further comprising a third device to reduce the pressure of the intermediate hydrovisbroken product.
48. The system of claim 47, wherein the third device comprises a valve.
49. The system of any one of claims 46 to 48, wherein a hydrogen feed stream is directed into the high pressure soaker vessel.
50. The system of claim 49, wherein excess hydrogen and any present non-condensable gases exit the high pressure soaker vessel to create an overhead stream.

51. The system of any one of claims 46 to 50, further configured to feed a light stream exiting the low pressure soaker vessel to an olefin saturation process to saturate olefins in the light stream.
52. The system of claim 51, wherein the olefin saturation process comprises a hydro-treater.
53. The system of claim 51 or claim 52, further configured to combine light hydrocarbons from the olefin saturation process with the partially hydrovisbroken product to create a partially upgraded product stream.
54. The system of any one of claims 51 to 53, further configured to recycle excess hydrogen from the olefin saturation process.
55. The system of any one of claims 29 to 30 or 32 to 54, wherein the hydrovisbreaking vessel is a coil visbreaking vessel.
56. The system of any one of claims 29 to 55, wherein the added hydrogen comprises both a hydrogen feed stream and a recycled hydrogen stream.

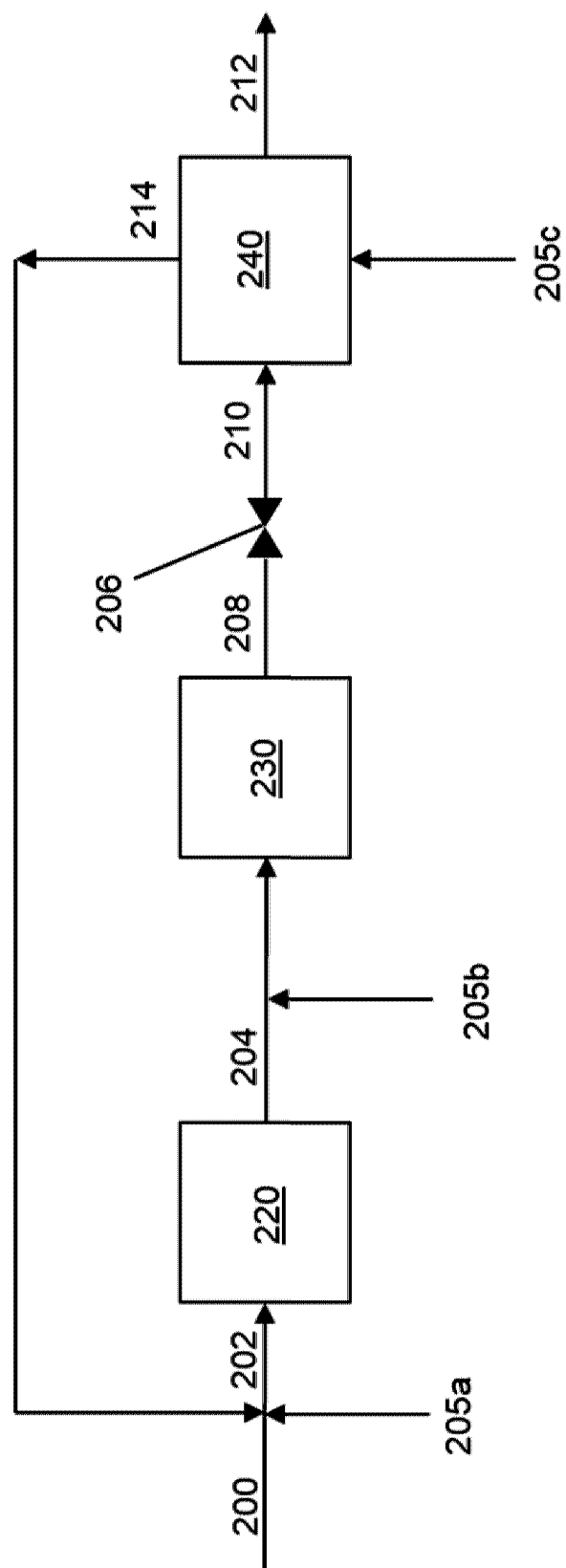


FIG. 1

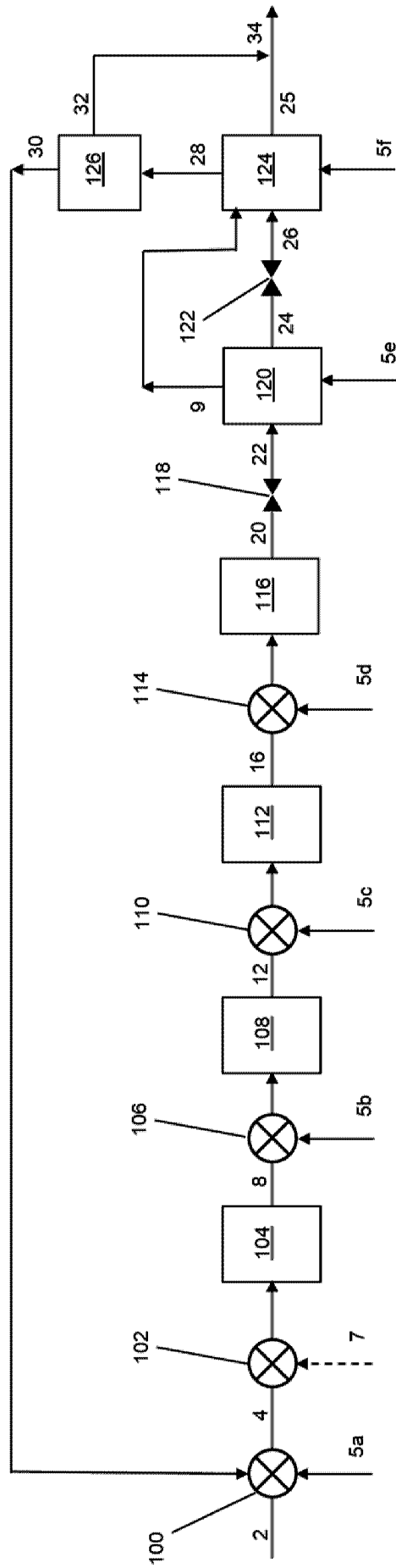


FIG. 2

