

We claim:

1. A process for hydrogenating a feedstream in a hydroprocessing reactor, the feedstream comprising a heavy hydrocarbon liquid component, the reactor also receiving a hydrogen gas input component, the reactor producing an effluent liquid stream and a separate effluent gas stream, the effluent gas stream comprising unreacted hydrogen, methane and heavier hydrocarbons, the process comprising:
 - a. compressing the effluent gas stream and a make-up hydrogen gas stream in a recycle gas compressor to produce a compressed recycle gas stream,
 - b. cooling the compressed recycle gas stream to a temperature in the range of +30°F (-1.1°C) to -40°F (-40°C);
 - c. contacting the cooled compressed recycle gas stream with a lean liquid solvent stream comprising C₄ to C₅ hydrocarbon components in an absorption zone to absorb the methane and heavier hydrocarbons from the compressed recycle gas stream to produce a hydrogen-rich gas stream containing 90 to 99 mol% hydrogen and a rich liquid solvent stream;
 - d. recovering the hydrogen-rich gas stream from the absorption zone;
 - e. adding the hydrogen-rich gas stream to the hydroprocessing reactor feedstream as the hydrogen gas input component; and
 - f. flashing the rich liquid solvent stream in at least one flashing stage to produce the lean liquid solvent stream comprising C₄ to C₅ hydrocarbon components present in the compressed recycle gas stream for contacting the cooled compressed recycle gas stream in step (c), and to produce a methane and heavier hydrocarbons gas product stream.

2. The process of claim 1, wherein the hydroprocessing reactor is selected from the group consisting of hydrodesulfurization, hydrocracking, hydrodenitrification, hydrodealkylation and hydrotreating reactors.

3. The process of claim 2, wherein the reactor is a hydrocracking reactor operating at a pressure in the range of 500 psig (35.1 kg/cm²g) to 5,000 psig (351.5 kg/cm²g).

4. The process of one of claims 2 or 3, wherein the hydrocracking reactor is operated at a pressure in the range of 1,000 psig (70.3 kg/cm²g) to 3,000 psig (210.9 kg/cm²g).

5. The process of claim 2, wherein the reactor is selected from the group consisting of hydrodealkylation and hydrotreating, and the reactor is operated at a pressure in the range of 200 psig (14.1 kg/cm²g) to 3,000 psig (210.9 kg/cm²g).

6. The process of one of claims 1 or 2, wherein the effluent liquid product and gas streams from the reactor are passed through a high pressure separator operating at a pressure in the range of 200 psig (14.1 kg/cm²g) to 5,000 psig (351.5 kg/cm²g).

7. The process of one of claims 1 or 2, wherein the compressed recycle gas stream and lean liquid solvent stream are contacted in the absorption zone at a pressure in the range of 200 psig (14.1 kg/cm²g) to 5,000 psig (351.5 kg/cm²g).

8. The process of claim 7, wherein the compressed recycle gas stream and lean liquid solvent stream are contacted in the absorption zone at a pressure in the range of 200 psig (14.1 kg/cm²g) to 3,000 psig (210.9 kg/cm²g).
9. The process of any of the preceding claims, wherein the hydrogen gas input component of the reactor feed stream contains 90-99 mol % hydrogen.
10. The process of any of claims 1 to 8, wherein the hydrogen gas input component includes a separate high purity make-up gas stream.
11. The process of claim 10, wherein the high-purity make-up gas stream contains 95-99.99 mol% hydrogen.
12. The process of claim 1, wherein the effluent gas stream is mixed with a low purity make-up gas stream and compressed in the recycle gas compressor to form the compressed recycle gas stream.
13. The process of any of the preceding claims, wherein the compressed recycle gas stream is comprised of compressed effluent gas stream and a compressed low purity make-up gas stream.

14. The process of claim 1, wherein a portion of the gas stream exiting the recycle gas compressor is fed directly to the reactor as a quench gas stream to maintain the temperature of the catalyst in the reactor within a predetermined range.

15. The process of claim 12, wherein the low purity make-up gas stream contains 50-99.99 mol% hydrogen.

16. The process of claim 12, wherein the low purity make-up gas stream contains 70-99.99 mol% hydrogen.

17. The process of claim 15, wherein the low purity make-up gas stream contains 50-90 mol% hydrogen.

18. The process of claim 2, wherein the heavy hydrocarbon liquid component feed contains sulfur, and the methane and heavier hydrocarbon gas product stream obtained in step (f) contains hydrogen sulfide, the process including the further steps following step (f) of:

g. contacting the methane and heavier hydrocarbon gas product with a lean amine solution in a treatment zone for removing the hydrogen sulfide and thereby providing a sweetened methane and heavier hydrocarbon gas product;

h. recovering the hydrogen sulfide-rich amine solution from the treatment zone;

and

i. passing the hydrogen sulfide-rich amine solution through a regeneration column for producing a lean amine solution for contacting in step (g).

19. The process of any of the preceding claims, wherein the compressed recycle gas stream is cooled to a temperature between 0°F (-17.9°C) and -20°F (-28.9°C).

20. The process of claim 19, wherein the compressed recycle gas stream is cooled to a temperature between -10°F (-23.3°C) to -15° F (-26.1°C).

21. The process of claim 1, wherein the compressed recycle gas stream contains water and the compressed recycle gas stream is co-chilled with ethylene glycol and the ethylene glycol/water mixture is separated from the chilled hydrocarbon gas and hydrocarbon liquid streams prior to entering the absorber.

22. The process of claim 1, wherein the heavy hydrocarbon component is selected from the group consisting of naphtha, kerosene, diesel, light vacuum gas oil, heavy vacuum gas oil, de-metalized oil, coker gas oil, resid, fuel oil and aromatics.

23. The process of claim 1, wherein the recovered hydrogen-rich gas stream from the absorption zone is further cross heat exchanged with the compressed recycle gas stream.

24. The process of claim 1, wherein the cooled compressed recycle gas stream is contacted in step (c) with the lean liquid solvent stream in counter-current flow.

25. The process of claim 1, wherein the lean liquid solvent stream enters the absorption zone at a temperature in the range of +30°F (-1.1°C) to -40°F (-40°C).

26. The process of claim 25, wherein the lean liquid solvent stream enters the absorption zone at a temperature in the range of 0°F (-17.8°C) to -20°F (-28.9°C).

27. The process of claim 26, wherein the lean liquid solvent stream enters the absorption zone at a temperature in the range of -10°F (-23.3°C) to -15°F (-26.1°C).

28. The process of any of the preceding claims, wherein the rich liquid solvent stream passes through at least two successive flash separators.

29. The process of claim 28, wherein the separated gases from the first of the at least two successive flash separators are compressed and returned to the absorption zone of step (c).

30. The process of claim 28, wherein the at least two flash separators are at least two-phase gas-liquid separation drums.

31. The process of claim 28, wherein the at least two successive flash separators operate at successively lower pressures than the operating pressure in the absorption zone.
32. The process of claim 6, wherein the separated liquid product from the high pressure separator is let down in pressure to produce a low pressure liquid and gas stream.
33. The process of claim 32, wherein the low pressure liquid and gas stream are separated in a low pressure separator to produce a low pressure hydrogen-rich gas stream.
34. The process of claim 33, wherein the low pressure hydrogen-rich gas stream is compressed and co-processed with the compressed recycle gas in step (b).
35. The process of claim 10, wherein the separate high purity make-up hydrogen gas stream bypasses the recycle gas compressor.
36. The process of claim 1, wherein the combined stream compressed in step (a) contains up to 85 mol% hydrogen.
37. A process for hydrogenating a feedstream in a hydroprocessing reactor, the feedstream comprising a heavy hydrocarbon liquid component, the reactor also

receiving a hydrogen gas input component, the reactor producing an effluent liquid stream and a separate effluent gas stream, the effluent gas stream comprising unreacted hydrogen, methane and heavier hydrocarbons, the process comprising:

- a. compressing the effluent gas stream and a make-up hydrogen gas stream in a recycle gas compressor designed to compress gases with average molecular weights greater than five to produce a compressed recycle gas stream,
- b. cooling the compressed recycle gas stream to a temperature in the range of +30°F (-1.1°C) to -40°F (-40°C);
- c. contacting the cooled compressed recycle gas stream with a lean liquid solvent stream comprising C₄ to C₅ hydrocarbon components in an absorption zone to absorb the methane and heavier hydrocarbons from the compressed recycle gas stream to produce a hydrogen-rich gas stream containing 90 to 99 mol% hydrogen having an average molecular weight between two and three and a rich liquid solvent stream;
- d. recovering the hydrogen-rich gas stream from the absorption zone;
- e. adding the hydrogen-rich gas stream to the hydroprocessing reactor feedstream as the hydrogen gas input component; and
- f. flashing the rich liquid solvent stream in at least one flashing stage to produce the lean liquid solvent stream comprising C₄ to C₅ hydrocarbon components present in the compressed recycle gas stream for contacting the cooled compressed recycle gas stream in step (c), and to produce a methane and heavier hydrocarbons gas product stream.

CLAIMS

1. In a process for hydrogenating a feedstream in a hydroprocessing reactor, the feedstream comprising a heavy hydrocarbon liquid component and a hydrogen gas input component, the hydrogen gas input component comprising a recycle hydrogen gas stream and a make-up hydrogen gas stream, the reactor producing an effluent liquid stream and a separate effluent gas stream, the effluent gas stream comprising unreacted hydrogen and methane and heavier hydrocarbons, the improvement comprising:
 - a. compressing the effluent gas stream and the make-up hydrogen gas stream in a recycle gas compressor to produce a compressed recycle gas stream,
 - b. cooling the compressed recycle gas stream to a temperature in the range of +30°F (-1.1°C) to -40°F (-40°C);
 - c. contacting the cooled compressed recycle gas stream with a lean liquid solvent stream comprising C₄ to C₅ hydrocarbon components in an absorption zone to absorb the methane and heavier hydrocarbon from the compressed recycle gas stream to produce a hydrogen-rich gas stream containing 90 to 99 mol% hydrogen and a rich liquid solvent stream;
 - d. recovering the hydrogen-rich gas stream from the absorption zone;
 - e. adding the hydrogen-rich gas stream to the hydroprocessing reactor feedstream as the recycle gas stream; and
 - f. flashing the rich liquid solvent stream in at least one flashing stage to produce the lean liquid solvent stream comprising C₄ to C₅ hydrocarbon components present in the compressed recycle gas stream for contacting the cooled compressed recycle gas stream in step (c), and to produce a methane and heavier hydrocarbon gas product stream.

2. A process for hydrogenating a feedstream in a hydroprocessing reactor, the feedstream comprising a heavy hydrocarbon liquid component, the reactor also receiving a hydrogen gas input component, the reactor producing an effluent liquid stream and a separate effluent gas stream, the effluent gas stream comprising unreacted hydrogen, methane and heavier hydrocarbons, the process comprising:

a. compressing the effluent gas stream and a make-up hydrogen gas stream in a recycle gas compressor designed to compress gases with average molecular weights greater than five to produce a compressed recycle gas stream,

b. cooling the compressed recycle gas stream to a temperature in the range of +30°F (-1.1°C) to -40°F (-40°C);

c. contacting the cooled compressed recycle gas stream with a lean liquid solvent stream comprising C₄ to C₅ hydrocarbon components in an absorption zone to absorb the methane and heavier hydrocarbons from the compressed recycle gas stream to produce a hydrogen-rich gas stream containing 90 to 99 mol% hydrogen having an average molecular weight between two and three and a rich liquid solvent stream;

d. recovering the hydrogen-rich gas stream from the absorption zone;

e. adding the hydrogen-rich gas stream to the hydroprocessing reactor feedstream as the hydrogen gas input component; and

f. flashing the rich liquid solvent stream in at least one flashing stage to produce the lean liquid solvent stream comprising C₄ to C₅ hydrocarbon components present in the compressed recycle gas stream for contacting the cooled compressed recycle gas stream in step (c), and to produce a methane and heavier hydrocarbons gas product stream.

3. The process of claim 1 or 2, wherein the hydroprocessing reactor is selected from the group consisting of hydrosulfurization, hydrocracking, hydrodenitrification, hydrodealkylation and hydrotreating reactors.
4. The process of claim 3, wherein the reactor is a hydrocracking reactor operating at a pressure in the range of 500 psig (35.1 kg/cm²g) to 5,000 psig (351.5 kg/cm²g).
5. The process of claim 4, wherein the hydrocracking reactor is operated at a pressure in the range of 1,000 psig (70.3 kg/cm²g) to 3,000 psig (210.9 kg/cm²g).
6. The process of claim 3, wherein the reactor is selected from the group consisting of hydrodealkylation and hydrotreating, and the reactor is operated at a pressure in the range of 200 psig (14.1 kg/cm²g) to 3,000 psig (210.9 kg/cm²g).
7. The process of claim 3, wherein the effluent liquid product and gas streams from the reactor are passed through a high pressure separator operating at a pressure in the range of 200 psig (14.1 kg/cm²g) to 5,000 psig (351.5 kg/cm²g).
8. The process of claim 3, wherein the compressed recycle gas stream and lean liquid solvent stream are contacted in the absorption zone at a pressure in the range of 200 psig (14.1 kg/cm²g) to 5,000 psig (351.5 kg/cm²g).

9. The process of claim 8, wherein the compressed recycle gas stream and lean liquid solvent stream are contacted in the absorption zone at a pressure in the range of 200 psig (14.1 kg/cm²g) to 3,000 psig (210.9 kg/cm²g).
10. The process of claim 1 or 2, wherein the hydrogen gas input component of the reactor feed stream contains 90-99 mol % hydrogen.
11. The process of claim 1 or 2, wherein the hydrogen gas input component comprises a compressed recycle gas stream and a high purity make-up gas stream.
12. The process of claim 11, wherein the high-purity make-up gas stream contains 95-99.99 mol% hydrogen.
13. The process of claim 1 or 2, wherein the effluent gas stream is mixed with a low purity make-up gas stream and compressed in the recycle gas compressor to form the compressed recycle gas stream.
14. The process of claim 1 or 2, wherein the compressed recycle gas stream is comprised of compressed effluent gas stream and a compressed low purity make-up gas stream.
15. The process of claim 1 or 2, wherein a portion of the gas stream exiting the recycle gas compressor is fed directly to the reactor as a quench gas stream to maintain the temperature of the catalyst in the reactor within a predetermined range.

16. The process of claim 13, wherein the low purity make-up gas stream contains 50-99.99 mol% hydrogen.
17. The process of claim 13, wherein the low purity make-up gas stream contains 70- 99.99 mol% hydrogen.
18. The process of claim 16, wherein the low purity make-up gas stream contains 50-90 mol% hydrogen.
19. The process of claim 3, wherein the heavy hydrocarbon liquid component feed contains sulfur, and the methane and heavier hydrocarbon gas product stream obtained in step (f) contains hydrogen sulfide, the process including the further steps following step (f) of:
- g. contacting the methane and heavier hydrocarbon gas product with a lean amine solution in a treatment zone for removing the hydrogen sulfide and thereby providing a sweetened methane and heavier hydrocarbon gas product;
 - h. recovering the hydrogen sulfide-rich amine solution from the treatment zone; and
 - i. passing the hydrogen sulfide-rich amine solution through a regeneration column for producing a lean amine solution for contacting in step (g).
20. The process of claim 1 or 2, wherein the compressed recycle gas stream is cooled to a temperature between 0°F (-17.9°C) and -20°F (-28.9°C).

21. The process of claim 20, wherein the compressed recycle gas stream is cooled to a temperature between -10°F (-23.3°C) to -15° F (-26.1°C).
22. The process of claim 1 or 2, wherein the compressed recycle gas stream contains water and the compressed recycle gas stream is co-chilled with ethylene glycol and the ethylene glycol/water mixture is separated from the chilled hydrocarbon gas and hydrocarbon liquid streams prior to entering the absorber.
23. The process of claim 1 or 2, wherein the heavy hydrocarbon component is selected from the group consisting of naphtha, kerosene, diesel, light vacuum gas oil, heavy vacuum gas oil, de-metalized oil, coker gas oil, resid, fuel oil and aromatics.
24. The process of claim 1 or 2, wherein the recovered hydrogen-rich gas stream from the absorption zone is further cross heat exchanged with the compressed recycle gas stream.
25. The process of claim 1 or 2, wherein the cooled compressed recycle gas stream is contacted in step (c) with the lean liquid solvent stream in counter-current flow.
26. The process of claim 1 or 2, wherein the lean liquid solvent stream enters the absorption zone at a temperature in the range of +30°F (-1.1°C) to -40°F (-40°C).
27. The process of claim 26, wherein the lean liquid solvent stream enters the absorption zone at a temperature in the range of 0°F (-17.8°C) to -20°F (-28.9°C).

28. The process of claim 27, wherein the lean liquid solvent stream enters the absorption zone at a temperature in the range of -10°F (-23.3°C) to -15°F (-26.1°C).
29. The process of claim 1 or 2, wherein the rich liquid solvent stream passes through at least two successive flash separators.
30. The process of claim 29, wherein the separated gases from the first of the at least two successive flash separators are compressed and returned to the absorption zone of step (c).
31. The process of claim 29, wherein the at least two flash separators are at least two-phase gas-liquid separation drums.
32. The process of claim 29, wherein the at least two successive flash separators operate at successively lower pressures than the operating pressure in the absorption zone.
33. The process of claim 7, wherein the separated liquid product from the high pressure separator is let down in pressure to produce a low pressure liquid and gas stream.
34. The process of claim 33, wherein the low pressure liquid and gas stream are separated in a low pressure separator to produce a low pressure hydrogen-rich gas stream.

35. The process of claim 34, wherein the low pressure hydrogen-rich gas stream is compressed and co-processed with the compressed recycle gas in step (b).
36. The process of claim 11, wherein the separate high purity make-up hydrogen gas stream bypasses the recycle gas compressor.
37. The process of claim 1 or 2, wherein the combined stream compressed in step (a) contains up to 85 mol% hydrogen.