

## Claims:

1. An integrated hydrotreating and steam pyrolysis process for the direct processing of crude oil to produce olefinic and aromatic petrochemicals, the process comprising:
  - a. charging the crude oil and hydrogen to a hydroprocessing zone operating under conditions effective to produce a hydroprocessed effluent having a reduced content of contaminants, an increased paraffinicity, reduced Bureau of Mines Correlation Index, and an increased American Petroleum Institute gravity;
  - b. thermally cracking hydroprocessed effluent in the presence of steam in a steam pyrolysis zone to produce a mixed product stream;
  - c. separating the thermally cracked mixed product stream into hydrogen, olefins, aromatics and pyrolysis fuel oil;
  - d. purifying hydrogen recovered in step (c) and recycling it to step (a);
  - e. recovering olefins and aromatics from the separated mixed product stream; and
  - f. recovering pyrolysis fuel oil from the separated mixed product stream.
2. The integrated process of claim 1, further comprising separating the hydroprocessed effluent from the hydroprocessing zone into a heavy fraction and a light fraction in a hydroprocessed effluent separation zone, wherein the light fraction is the hydroprocessed effluent that is thermally cracked in step (b), and blending the heavy fraction with pyrolysis fuel oil recovered in step (f).
3. The integrated process of claim 2, wherein the hydroprocessed effluent separation zone is a flash separation apparatus.

4. The integrated process of claim 2, wherein the hydroprocessed effluent separation zone is a physical or mechanical apparatus for separation of vapors and liquids.

5. The integrated process of claim 1, wherein

step (c) comprises

compressing the thermally cracked mixed product stream with plural compression stages;

subjecting the compressed thermally cracked mixed product stream to caustic treatment to produce a thermally cracked mixed product stream with a reduced content of hydrogen sulfide and carbon dioxide;

compressing the thermally cracked mixed product stream with a reduced content of hydrogen sulfide and carbon dioxide;

dehydrating the compressed thermally cracked mixed product stream with a reduced content of hydrogen sulfide and carbon dioxide;

recovering hydrogen from the dehydrated compressed thermally cracked mixed product stream with a reduced content of hydrogen sulfide and carbon dioxide; and

obtaining olefins and aromatics as in step (e) and pyrolysis fuel oil as in step (f) from the remainder of the dehydrated compressed thermally cracked mixed product stream with a reduced content of hydrogen sulfide and carbon dioxide;

and

step (d) comprises purifying recovered hydrogen from the dehydrated compressed thermally cracked mixed product stream with a reduced content of hydrogen sulfide and carbon dioxide for recycle to the hydroprocessing zone.

6. The integrated process of claim 5, wherein recovering hydrogen from the dehydrated compressed thermally cracked mixed product stream with a reduced content of hydrogen sulfide and carbon dioxide further comprises separately recovering methane for use as fuel for burners and/or heaters in the thermal cracking step.
7. The integrated process of claim 1 wherein the thermal cracking step comprises heating hydroprocessed effluent in a convection section of a steam pyrolysis zone, separating the heated hydroprocessed effluent into a vapor fraction and a liquid fraction, passing the vapor fraction to a pyrolysis section of a steam pyrolysis zone, and discharging the liquid fraction.
8. The integrated process of claim 7 wherein the discharged liquid fraction is blended with pyrolysis fuel oil recovered in step (f).
9. The integrated process of claim 6 wherein separating the heated hydroprocessed effluent into a vapor fraction and a liquid fraction is with a vapor-liquid separation device based on physical and mechanical separation.
10. The integrated process of claim 9 wherein the vapor-liquid separation device includes  
a pre-rotational element having an entry portion and a transition portion, the entry portion having an inlet for receiving the flowing fluid mixture and a curvilinear conduit,  
a controlled cyclonic section having  
an inlet adjoined to the pre-rotational element through convergence of the curvilinear conduit and the cyclonic section,

a riser section at an upper end of the cyclonic member through which vapors pass;  
and  
a liquid collector/settling section through which liquid passes.

11. The integrated process of claim 1, further comprising

separating the hydroprocessing zone reactor effluents in a high pressure separator to recover a gas portion that is cleaned and recycled to the hydroprocessing zone as an additional source of hydrogen, and liquid portion, and

separating the liquid portion from the high pressure separator in a low pressure separator into a gas portion and a liquid portion, wherein the liquid portion from the low pressure separator is the hydroprocessed effluent subjected to thermal cracking and the gas portion from the low pressure separator is combined with the mixed product stream after the steam pyrolysis zone and before separation in step (c).

12. The integrated process of claim 2, further comprising

separating the hydroprocessing zone reactor effluents in a high pressure separator to recover a gas portion that is cleaned and recycled to the hydroprocessing zone as an additional source of hydrogen, and liquid portion,

separating the liquid portion from the high pressure separator in a low pressure separator into a gas portion and a liquid portion, wherein the liquid portion from the low pressure separator is the hydroprocessed effluent subjected to separation into a light fraction and a heavy fraction, and the gas portion from the low pressure separator is combined with the mixed product stream after the steam pyrolysis zone and before separation in step (c).

## CLAIMS

1. An integrated hydrotreating and steam pyrolysis process for the direct processing of crude oil to produce olefinic and aromatic petrochemicals, the process comprising:
  - a. charging the crude oil and hydrogen to a hydroprocessing zone operating under conditions effective to produce a hydroprocessed effluent having a reduced content of contaminants, an increased paraffinicity, reduced Bureau of Mines Correlation Index, and an increased American Petroleum Institute gravity;
  - b. thermally cracking at least a portion of the hydroprocessed effluent by heating hydroprocessed effluent in a convection section of a steam pyrolysis zone, separating the heated hydroprocessed effluent into a vapor fraction and a liquid fraction, passing the vapor fraction to a pyrolysis section of a steam pyrolysis zone to produce a mixed product stream, and discharging the liquid fraction, wherein separating the heated hydroprocessed effluent is with a vapor-liquid separation device that includes
    - a pre-rotational element having an entry portion and a transition portion, the entry portion having an inlet for receiving the flowing fluid mixture and a curvilinear conduit,
    - a controlled cyclonic section having an inlet adjoined to the pre-rotational element through convergence of the curvilinear conduit and the cyclonic section and a riser section at an upper end of the cyclonic member through which vapors pass, and
    - a liquid collector/settling section through which liquid passes as the discharged liquid fraction; ;
  - c. separating the thermally cracked mixed product stream into hydrogen, olefins, aromatics and pyrolysis fuel oil;
  - d. purifying hydrogen recovered in step (c) and recycling it to step (a);
  - e. recovering olefins and aromatics from at least a portion of the separated mixed product stream; and
  - f. recovering pyrolysis fuel oil from at least a portion of the separated mixed product stream.
2. The integrated process of claim 1, further comprising separating the hydroprocessed effluent from the hydroprocessing zone into a heavy fraction and a light fraction in a

hydroprocessed effluent separation zone, wherein the light fraction is the hydroprocessed effluent that is thermally cracked in step (b),.

3. The integrated process of claim 2, wherein the hydroprocessed effluent separation zone is a flash separation apparatus.

4. The integrated process of claim 2, wherein the hydroprocessed effluent separation zone is a physical or mechanical apparatus for separation of vapors and liquids.

5. The integrated process of claim 4, wherein the hydroprocessed effluent separation zone comprises a flash vessel having at it inlet a second vapor-liquid separation device including

a pre-rotational element having an entry portion and a transition portion, the entry portion having an inlet for receiving the flowing fluid mixture and a curvilinear conduit,

a controlled cyclonic section having an inlet adjoined to the pre-rotational element through convergence of the curvilinear conduit and the cyclonic section, and a riser section at an upper end of the cyclonic member through which the light fraction passes,

wherein a bottom portion of the flash vessel serves as a collection and settling zone for the heavy fraction prior to passage of all or a portion of said heavy fraction.

6. The integrated process of claim 2, further comprising

separating the hydroprocessing zone reactor effluents in a high pressure separator to recover a gas portion that is cleaned and recycled to the hydroprocessing zone as an additional source of hydrogen, and liquid portion,

separating the liquid portion from the high pressure separator in a low pressure separator into a gas portion and a liquid portion, wherein the liquid portion from the low pressure separator is the hydroprocessed effluent subjected to separation into a light fraction and a heavy fraction, and the gas portion from the low pressure separator is combined with the mixed product stream after the steam pyrolysis zone and before separation in step (c).

7. The integrated process of claim 2, further comprising blending the heavy fraction with the pyrolysis fuel oil recovered in step (f).

8. The integrated process of claim 1, wherein  
step (c) comprises  
compressing the thermally cracked mixed product stream with plural compression stages;  
subjecting the compressed thermally cracked mixed product stream to caustic treatment to produce a thermally cracked mixed product stream with a reduced content of hydrogen sulfide and carbon dioxide;  
compressing the thermally cracked mixed product stream with a reduced content of hydrogen sulfide and carbon dioxide;  
dehydrating the compressed thermally cracked mixed product stream with a reduced content of hydrogen sulfide and carbon dioxide;  
recovering hydrogen from the dehydrated compressed thermally cracked mixed product stream with a reduced content of hydrogen sulfide and carbon dioxide; and  
obtaining olefins and aromatics as in step (e) and pyrolysis fuel oil as in step (f) from the remainder of the dehydrated compressed thermally cracked mixed product stream with a reduced content of hydrogen sulfide and carbon dioxide;  
and  
step (d) comprises purifying recovered hydrogen from the dehydrated compressed thermally cracked mixed product stream with a reduced content of hydrogen sulfide and carbon dioxide for recycle to the hydroprocessing zone.
9. The integrated process of claim 8, wherein recovering hydrogen from the dehydrated compressed thermally cracked mixed product stream with a reduced content of hydrogen sulfide and carbon dioxide further comprises separately recovering methane for use as fuel for burners and/or heaters in the thermal cracking step.
10. The integrated process of claim 1 wherein the discharged liquid fraction is blended with pyrolysis fuel oil recovered in step (f).
11. The integrated process of claim 1, further comprising

separating the hydroprocessing zone reactor effluents in a high pressure separator to recover a gas portion that is cleaned and recycled to the hydroprocessing zone as an additional source of hydrogen, and liquid portion, and

separating the liquid portion from the high pressure separator in a low pressure separator into a gas portion and a liquid portion, wherein the liquid portion from the low pressure separator is the hydroprocessed effluent subjected to thermal cracking and the gas portion from the low pressure separator is combined with the mixed product stream after the steam pyrolysis zone and before separation in step (c).

12. An integrated hydrotreating and steam pyrolysis process for the direct processing of crude oil to produce olefinic and aromatic petrochemicals, the process comprising:

a. charging the crude oil and hydrogen to a hydroprocessing zone operating under conditions effective to produce a hydroprocessed effluent having a reduced content of contaminants, an increased paraffinicity, reduced Bureau of Mines Correlation Index, and an increased American Petroleum Institute gravity;

b. separating at least a portion of the hydroprocessed effluent from the hydroprocessing zone into a heavy fraction and a light fraction in a flash vessel having at its inlet a vapor-liquid separation device including

a pre-rotational element having an entry portion and a transition portion, the entry portion having an inlet for receiving the flowing fluid mixture and a curvilinear conduit,

a controlled cyclonic section having an inlet adjoined to the pre-rotational element through convergence of the curvilinear conduit and the cyclonic section and a riser section at an upper end of the cyclonic member through which the light fraction passes, and

wherein a bottom portion of the flash vessel serves as a collection and settling zone for the heavy fraction;

c. thermally cracking the light fraction from step (b) in the presence of steam in a steam pyrolysis zone to produce a mixed product stream;

d. separating the thermally cracked mixed product stream into hydrogen, olefins, aromatics and pyrolysis fuel oil;

e. purifying hydrogen recovered in step (d) and recycling it to step (a);

f. recovering olefins and aromatics from at least a portion of the separated mixed product stream; and

g. recovering pyrolysis fuel oil from at least a portion of the separated mixed product stream.

13. The integrated process of claim 12, further comprising blending the heavy fraction with pyrolysis fuel oil recovered in step (g).

14. The integrated process of claim 12 wherein the thermal cracking step comprises heating hydroprocessed effluent in a convection section of a steam pyrolysis zone, separating the heated hydroprocessed effluent into a vapor fraction and a liquid fraction, passing the vapor fraction to a pyrolysis section of a steam pyrolysis zone, and discharging the liquid fraction.

15. The integrated process of claim 14 wherein the discharged liquid fraction is blended with pyrolysis fuel oil recovered in step (f).

16. The integrated process of claim 14 wherein separating the heated hydroprocessed effluent into a vapor fraction and a liquid fraction is with a second vapor-liquid separation device based on physical and mechanical separation.

17. The integrated process of claim 14 wherein separating the heated hydroprocessed effluent into a vapor fraction and a liquid fraction is with a second vapor-liquid separation device comprising

a pre-rotational element having an entry portion and a transition portion, the entry portion having an inlet for receiving the flowing fluid mixture and a curvilinear conduit,

a controlled cyclonic section having an inlet adjoined to the pre-rotational element through convergence of the curvilinear conduit and the cyclonic section and a riser section at an upper end of the cyclonic member through which vapors pass,

and

a liquid collector/settling section through which liquid passes as the discharged liquid fraction.

18. The integrated process of claim 12, further comprising
  - separating the hydroprocessing zone reactor effluents in a high pressure separator to recover a gas portion that is cleaned and recycled to the hydroprocessing zone as an additional source of hydrogen, and liquid portion,
  - separating the liquid portion from the high pressure separator in a low pressure separator into a gas portion and a liquid portion, wherein the liquid portion from the low pressure separator is the hydroprocessed effluent subjected to separation in step (b), and the gas portion from the low pressure separator is combined with the mixed product stream produced in step (c) before separation in step (d).
19. An integrated hydrotreating and steam pyrolysis process for the direct processing of crude oil to produce olefinic and aromatic petrochemicals, the process comprising:
  - a. charging the crude oil and hydrogen to a hydroprocessing zone operating under conditions effective to produce a hydroprocessed effluent having a reduced content of contaminants, an increased paraffinicity, reduced Bureau of Mines Correlation Index, and an increased American Petroleum Institute gravity;
  - b. separating at least a portion of the hydroprocessed effluent from the hydroprocessing zone into a heavy fraction and a light fraction in a hydroprocessed effluent separation zone;
  - c. thermally cracking the light fraction from step (b) in the presence of steam in a steam pyrolysis zone to produce a mixed product stream;
  - d. separating the thermally cracked mixed product stream into hydrogen, olefins, aromatics and pyrolysis fuel oil;
  - e. purifying hydrogen recovered in step (d) and recycling it to step (a);
  - f. recovering olefins and aromatics from at least a portion of the separated mixed product stream;
  - g. recovering pyrolysis fuel oil from at least a portion of the separated mixed product stream; and

- h. blending the heavy fraction from step (b) with pyrolysis fuel oil recovered in step (f).
20. The integrated process of claim 19, wherein the hydroprocessed effluent separation zone is a flash separation apparatus.
21. The integrated process of claim 19, wherein the hydroprocessed effluent separation zone is a physical or mechanical apparatus for separation of vapors and liquids.
22. The integrated process of claim 19 wherein the thermal cracking step comprises heating hydroprocessed effluent in a convection section of a steam pyrolysis zone, separating the heated hydroprocessed effluent into a vapor fraction and a liquid fraction, passing the vapor fraction to a pyrolysis section of a steam pyrolysis zone, and discharging the liquid fraction.
23. The integrated process of claim 22 wherein the discharged liquid fraction is blended with pyrolysis fuel oil recovered in step (f).
24. The integrated process of claim 22 wherein separating the heated hydroprocessed effluent into a vapor fraction and a liquid fraction is with a vapor-liquid separation device based on physical and mechanical separation.
25. The integrated process of claim 19, further comprising  
separating the hydroprocessing zone reactor effluents in a high pressure separator to recover a gas portion that is cleaned and recycled to the hydroprocessing zone as an additional source of hydrogen, and liquid portion,  
separating the liquid portion from the high pressure separator in a low pressure separator into a gas portion and a liquid portion, wherein the liquid portion from the low pressure separator is the hydroprocessed effluent subjected to separation in step (b), and the gas portion from the low pressure separator is combined with the mixed product stream produced in step (c) before separation in step (d).
26. An integrated hydrotreating and steam pyrolysis process for the direct processing of crude oil to produce olefinic and aromatic petrochemicals, the process comprising:

a. charging the crude oil and hydrogen to a hydroprocessing zone operating under conditions effective to produce a hydroprocessed effluent having a reduced content of contaminants, an increased paraffinicity, reduced Bureau of Mines Correlation Index, and an increased American Petroleum Institute gravity;

b. thermally cracking at least a portion of the hydroprocessed effluent by heating hydroprocessed effluent in a convection section of a steam pyrolysis zone, separating the heated hydroprocessed effluent into a vapor fraction and a liquid fraction, passing the vapor fraction to a pyrolysis section of a steam pyrolysis zone to produce a thermally cracked mixed product stream, and discharging the liquid;

c. separating the thermally cracked mixed product stream into hydrogen, olefins, aromatics and pyrolysis fuel oil;

d. purifying hydrogen recovered in step (c) and recycling it to step (a);

e. recovering olefins and aromatics from at least a portion of the separated mixed product stream;

f. recovering pyrolysis fuel oil from at least a portion of the separated mixed product stream; and

g. blending the discharged liquid from step (b) with pyrolysis fuel oil recovered in step (f).

27. The integrated process of claim 26, further comprising separating the hydroprocessed effluent from the hydroprocessing zone into a heavy fraction and a light fraction in a hydroprocessed effluent separation zone, wherein the light fraction is the hydroprocessed effluent that is thermally cracked in step (b).

28. The integrated process of claim 27, further comprising blending the heavy fraction with pyrolysis fuel oil recovered in step (f).

29. The integrated process of claim 27, wherein the hydroprocessed effluent separation zone is a flash separation apparatus.

30. The integrated process of claim 27, wherein the hydroprocessed effluent separation zone is a physical or mechanical apparatus for separation of vapors and liquids.

31. The integrated process of claim 37, wherein the hydroprocessed effluent separation zone comprises a flash vessel having at it inlet a vapor-liquid separation device including
- a pre-rotational element having an entry portion and a transition portion, the entry portion having an inlet for receiving the flowing fluid mixture and a curvilinear conduit,
  - a controlled cyclonic section having an inlet adjoined to the pre-rotational element through convergence of the curvilinear conduit and the cyclonic section and a riser section at an upper end of the cyclonic member through which the light fraction passes,
- wherein a bottom portion of the flash vessel serves as a collection and settling zone for the heavy fraction prior to passage of all or a portion of said heavy fraction.
32. The integrated process of claim 27, further comprising
- separating the hydroprocessing zone reactor effluents in a high pressure separator to recover a gas portion that is cleaned and recycled to the hydroprocessing zone as an additional source of hydrogen, and liquid portion,
  - separating the liquid portion from the high pressure separator in a low pressure separator into a gas portion and a liquid portion, wherein the liquid portion from the low pressure separator is the hydroprocessed effluent subjected to separation into a light fraction and a heavy fraction, and the gas portion from the low pressure separator is combined with the mixed product stream produced in step (b) before separation in step (c).
33. The integrated process of claim 26 wherein separating the heated hydroprocessed effluent in step (b) is with a vapor-liquid separation device based on physical and mechanical separation.
34. The integrated process of claim 26 wherein separating the heated hydroprocessed effluent in step (b) is with a vapor-liquid separation device that includes
- a pre-rotational element having an entry portion and a transition portion, the entry portion having an inlet for receiving the flowing fluid mixture and a curvilinear conduit,
  - a controlled cyclonic section having an inlet adjoined to the pre-rotational element through convergence of the curvilinear conduit and the cyclonic section and a riser section at an upper end of the cyclonic member through which vapors pass, and

a liquid collector/settling section through which liquid passes as the discharged liquid fraction.

35. The integrated process of claim 26, further comprising

separating the hydroprocessing zone reactor effluents in a high pressure separator to recover a gas portion that is cleaned and recycled to the hydroprocessing zone as an additional source of hydrogen, and liquid portion, and

separating the liquid portion from the high pressure separator in a low pressure separator into a gas portion and a liquid portion, wherein the liquid portion from the low pressure separator is the hydroprocessed effluent subjected to thermal cracking and the gas portion from the low pressure separator is combined with the mixed product stream produced in step (b) before separation in step (c).

36. An integrated hydrotreating and steam pyrolysis process for the direct processing of crude oil to produce olefinic and aromatic petrochemicals, the process comprising:

a. charging the crude oil and hydrogen to a hydroprocessing zone operating under conditions effective to produce a hydroprocessed effluent having a reduced content of contaminants, an increased paraffinicity, reduced Bureau of Mines Correlation Index, and an increased American Petroleum Institute gravity;

b. thermally cracking at least a portion of the hydroprocessed effluent in the presence of steam in a steam pyrolysis zone to produce a mixed product stream;

c. compressing the thermally cracked mixed product stream with plural compression stages;

subjecting the compressed thermally cracked mixed product stream to caustic treatment to produce a thermally cracked mixed product stream with a reduced content of hydrogen sulfide and carbon dioxide;

compressing the thermally cracked mixed product stream with a reduced content of hydrogen sulfide and carbon dioxide;

dehydrating the compressed thermally cracked mixed product stream with a reduced content of hydrogen sulfide and carbon dioxide;

recovering hydrogen from the dehydrated compressed thermally cracked mixed product stream with a reduced content of hydrogen sulfide and carbon dioxide;

d. purifying recovered hydrogen from the dehydrated compressed thermally cracked mixed product stream with a reduced content of hydrogen sulfide and carbon dioxide for recycle to the hydroprocessing zone;

e. recovering olefins and aromatics from the the remainder of the dehydrated compressed thermally cracked mixed product stream; and

f. recovering pyrolysis fuel oil from the remainder of the dehydrated compressed thermally cracked mixed product stream.

37. The integrated process of claim 36, wherein recovering hydrogen from the dehydrated compressed thermally cracked mixed product stream with a reduced content of hydrogen sulfide and carbon dioxide further comprises separately recovering methane for use as fuel for burners and/or heaters in the thermal cracking step.