CLAIMS

1. A process for producing C5 olefins from a mixed C5 feed, the process comprising:

feeding hydrogen and a mixed hydrocarbon stream comprising cyclopentadiene, linear C5 olefins, cyclic C5 olefins, and C6+ hydrocarbons to a catalytic distillation reactor system;

concurrently in the catalytic distillation reactor system:

separating the linear C5 olefins from the cyclic C5 olefins, C5 dienes, and C6+ hydrocarbons; and

selectively hydrogenating at least a portion of the C5 dienes to form additional linear C5 olefins;

withdrawing a liquid side draw from a stage below a mixed hydrocarbon feed location and a hydrogen feed location and above a main reboiler, at least partially vaporizing the liquid side draw in an intermediate reboiler, and returning the at least partially vaporized liquid side draw to the catalytic distillation reactor system;

recovering linear C5 olefins as an overhead distillate from the catalytic distillation reactor system; and

recovering cyclic C5 olefins as a bottoms product from the catalytic distillation reactor system.

2. The process of claim 1, further comprising operating the main reboiler of the catalytic distillation reactor system at a temperature of less than about 302°F.

3. A process for the selective hydrogenation of C5 dienes in a mixed C5 hydrocarbon stream, comprising:

feeding hydrogen and a C5-olefin containing stream comprising linear pentenes, dienes, acetylenes, and a diluent compound to a catalytic distillation reactor system;

concurrently in the catalytic distillation reactor system:

hydrogenating the acetylenes and dienes; and

fractionating the C5-olefin containing stream;

recovering an overheads fraction comprising the pentenes;

recovering a bottoms fraction;

wherein the catalytic distillation reactor system has at least three reaction zones, including:

a first reaction zone disposed below a C5-olefin containing stream feed elevation and containing a nickel-based hydrogenation catalyst;

a second reaction zone disposed above the C5-olefin containing stream feed elevation and containing a nickel-based hydrogenation catalyst; and

a third reaction zone disposed above the second reaction zone and containing a palladium-based hydrogenation catalyst;

purging a portion of the bottoms fraction;

reacting a remaining portion of the bottoms fraction in a total hydrogenation unit to convert cyclic C5 olefins to cyclopentane; and

recycling the cyclopentane to the catalytic distillation reactor system.

4. The process of claim 3, wherein the nickel-based hydrogenation catalyst comprises from 5 wt% to 30 wt% nickel, wherein the nickel-based hydrogenation catalyst is disposed on a diatomaceous earth support, has a BET surface area in the range from 20 m^2/g to 400 m^2/g, and has a pore volume in the range from 0.2 ml/g to 0.7 ml/g, and wherein the palladium-based hydrogenation catalyst comprises from 0.2 to 1.0 wt% palladium disposed on an alumina support.

5. A system for producing C5 olefins from a mixed C5 hydrocarbon feedstock, comprising:

a catalytic distillation reactor system for concurrently converting C5 dienes to C5 olefins and separating the mixed C5 hydrocarbon feedstock into an overheads olefin product and a bottoms product, the catalytic distillation reactor system having at least three reaction zones, including:

a first reaction zone disposed below a C5-olefin containing stream feed elevation and containing a nickel-based catalyst;

a second reaction zone disposed above the C5-olefin containing stream feed elevation and containing a nickel-based catalyst; and

a third reaction zone disposed above the second reaction zone and containing a palladium-based catalyst;

a feed line configured to feed a diluent compound to the catalytic distillation reactor system;

an analyzer for determining a density profile or a composition profile of the diluent compound within the catalytic distillation reactor system; and

a controller configured to adjust one or more operating parameters to maintain a set point density profile or composition profile of the diluent compound within the catalytic distillation reactor system.

6. The system of claim 5, further comprising a fractionator configured to concurrently (a) convert cyclopentadiene in a mixed hydrocarbon to dicyclopentadiene and produce a dimerization reactor effluent, and (b) separate the mixed hydrocarbon to form a bottoms fraction including the dicyclopentadiene and an overheads fraction comprising the mixed C5 hydrocarbon feedstock.
7. The system of claim 5, further comprising:

a dimerization reactor for converting cyclopentadiene in a mixed hydrocarbon to dicyclopentadiene and producing a dimerization reactor effluent; and

a separator for separating the dimerization reactor effluent to form a bottoms fraction including the dicyclopentadiene and an overheads fraction comprising the mixed C5 hydrocarbon feedstock.

8. The system of claim 5, further comprising a total hydrogenation reactor for converting cyclopentene in the bottoms product to cyclopentane.
9. The system of claim 8, further comprising a flow conduit for recycling an effluent from the total hydrogenation reactor to the catalytic distillation reactor system.
10. A process for the selective hydrogenation of C5 dienes in a mixed C5 hydrocarbon stream, comprising:

feeding hydrogen and a C5-olefin containing stream comprising linear pentenes, dienes, acetylenes, and a diluent compound to a catalytic distillation reactor system;

concurrently in the catalytic distillation reactor system:

hydrogenating the acetylenes and dienes; and

fractionating the C5-olefin containing stream;

recovering an overheads fraction comprising the pentenes;

recovering a bottoms fraction;

determining a concentration of the diluent compound at one or more column elevations; and

adjusting one or more column operating parameters to maintain a set point concentration or a concentration profile of the diluent compound at the one or more column elevations.

11. The process of claim 10, wherein the catalytic distillation reactor system includes an upper catalyst zone above a C5-olefin containing stream feed elevation and a lower catalyst zone below the C5-olefin containing stream feed elevation, the process comprising at least one of:

measuring a concentration of the diluent compound at an elevation below the lower catalyst zone;

measuring a concentration of the diluent compound at an elevation intermediate the upper and lower catalyst zones; or

measuring a concentration of the diluent compound at an elevation above the upper catalyst zone.

12. The process of claim 10, wherein the catalytic distillation reactor system includes an upper catalyst zone above a C5-olefin containing stream feed elevation and a lower catalyst zone below the C5-olefin containing stream feed elevation, the process comprising at least one of:

measuring a density of a liquid fraction at an elevation below the lower catalyst zone and determining the concentration of the diluent compound at the elevation below based upon the measured density;

measuring a density of a liquid fraction at an elevation intermediate the upper and lower catalyst zones and determining the concentration of the diluent compound at the elevation intermediate based upon the measured density; or

measuring a density of a liquid fraction at an elevation above the upper catalyst zone and determining the concentration of the diluent compound at the elevation above based upon the measured density.

13. The process of claim 10, wherein the diluent compound comprises cyclopentane, cyclopentene, or a combination thereof.

14. The process of claim 10, wherein the diluent compound comprises one or more hydrocarbons having a normal boiling point in the range from 100°F to 125°F.
15. The process of claim 10, wherein the diluent compound comprises one or more hydrocarbons having a specific gravity in the range from 0.7 to 0.8.
16. The process of claim 10, wherein a sample elevation used in the determining step is disposed proximate an elevation of maximum rate of change in concentration of the diluent compound within the catalytic distillation reactor system.
17. The process of claim 16, further comprising determining an elevation of maximum rate of change in concentration of the diluent compound within the catalytic distillation reactor system.
18. The process of claim 10, wherein the adjusting comprises at least one of:

    decreasing an overhead flow and increasing a reflux flow when a diluent compound concentration profile starts to move up the column and the reflux flow is below a column flooding value;

    increasing an overhead flow and decreasing reflux flow when a diluent compound concentration profile starts to move down the column and the reflux flow is above a minimum design value;

    decreasing a reboiler duty and an overhead flow when the diluent compound concentration profile starts to move up the column; or

    increasing a reboiler duty and an overhead flow when the diluent compound concentration profile starts to move down the column.
19. A process for the selective hydrogenation of C5 dienes in a mixed C5 hydrocarbon stream, comprising:

    feeding hydrogen and a C5-olefin containing stream comprising linear pentenes, dienes, acetylenes, cyclopentane and cyclopentene to a catalytic distillation reactor system;

    concurrently in the catalytic distillation reactor system:

        hydrogenating the acetylenes and dienes; and

        fractionating the C5-olefin containing stream;

    recovering an overheads fraction comprising the pentenes;

    recovering a bottoms fraction;

determining a density of a liquid fraction at one or more column elevations; and

adjusting one or more column operating parameters to maintain a set point density or density profile at the one or more column elevations.

20. The process of claim 19, wherein the catalytic distillation reactor system includes an upper catalyst zone above a C5-olefin containing stream feed elevation and a lower catalyst zone below the C5-olefin containing stream feed elevation, the process comprising at least one of:

measuring a density of the liquid fraction at an elevation below the lower catalyst zone;

measuring a density of the liquid fraction at an elevation intermediate the upper and lower catalyst zones; or

measuring a density of the liquid fraction at an elevation above the upper catalyst zone.

21. The process of claim 20, wherein the adjusting comprises at least one of:

decreasing an overhead flow and increasing a reflux flow when a density profile indicates a concentration of a target compound is starting to move up the column and the reflux flow is below a column flooding value;

increasing an overhead flow and decreasing reflux flow when a density profile indicates a concentration of a target compound is starting to move down the column and the reflux flow is above a minimum design value;

decreasing a reboiler duty and an overhead flow when the density profile indicates a concentration of a target compound is starting to move up the column; or

increasing a reboiler duty and an overhead flow when the density profile indicates a concentration of a target compound is starting to move down the column.

22. The process of claim 21, wherein the target compound comprises cyclopentane, cyclopentene, or a combination thereof.

23. A method for controlling a catalytic distillation reactor system, comprising:

feeding one or more reactants and an inert compound to a catalytic distillation reactor system having one or more reaction zones;

concurrently in the catalytic distillation reactor system:

converting the reactants to one or more products; and

fractionating the reactants and products;

recovering an overheads fraction;

recovering a bottoms fraction;

determining a concentration of the inert compound at one or more column elevations; and

adjusting one or more column operating parameters to maintain a set point concentration or a concentration profile of the inert compound at the one or more column elevations.

24. A system for producing C5 olefins from a mixed C5 hydrocarbon feedstock, comprising:

a catalytic distillation reactor system, including one or more reaction zones, for concurrently converting C5 dienes to C5 olefins and separating the C5 hydrocarbon feedstock into an overheads olefin product and a bottoms product;

a feed line configured to feed a diluent compound to the catalytic distillation reactor system;

an analyzer for determining a density profile or a composition profile of the diluent compound within the catalytic distillation reactor system; and

a controller configured to adjust one or more operating parameters to maintain a set point density profile or composition profile of the diluent compound within the catalytic distillation reactor system.

25. The system of claim 24, wherein the analyzer is a density measurement device, the controller further configured to convert a measured density to an estimated composition.

26. A system for producing C5 olefins from a steam cracker C5 feed, the system comprising:

a low temperature / low pressure distillation column configured to concurrently (a) fractionate a mixed hydrocarbon stream comprising cyclopentadiene, linear C5 olefins, cyclic C5 olefins, C5 dienes, and C6+ hydrocarbons to recover an overhead distillate comprising linear and cyclic C5 olefins and C5 dienes and (b) dimerize the cyclopentadiene; and

a catalytic distillation reactor system configured to concurrently (a) separate the linear C5 olefins from the cyclic C5 olefins and C5 dienes in the overhead distillate and (b) selectively hydrogenate at least a portion of the C5 dienes in the overhead distillate to form additional C5 olefins, and further the system comprising:

a total hydrogenation unit configured to convert the cyclic C5 olefines recovered as a bottoms product from the catalytic distillation reaction system to cyclopentene.