CLAIMS

1. A process for upgrading a petroleum-based composition comprising:

combining a supercritical water stream with a pressurized, heated petroleum-based composition in a mixing device to create a combined feed stream;

introducing the combined feed stream into an upgrading reactor system comprising at least one downflow supercritical upgrading reactor operating at a temperature greater than a critical temperature of water and a pressure greater than a critical pressure of water;

where the downflow supercritical upgrading reactor comprises a first catalyst layer and a second catalyst layer, the second catalyst layer disposed vertically below the first catalyst layer in the downflow supercritical upgrading reactor,

where the first catalyst layer is a heterogeneous porous metal containing catalyst having a first void volume ratio and the second catalyst layer is a heterogeneous porous metal containing catalyst having a second void volume ratio,

where the second void volume ratio differs from the first void volume ratio, and

where the downflow supercritical upgrading reactor includes one or more purging fluid inlets disposed on one or more side locations of the downflow supercritical upgrading reactor proximate the first catalyst layer, the second catalyst layer, or both;

passing the combined feed stream through the first catalyst layer and the second catalyst layer, where light hydrocarbons in the combined feed stream at least partially flow through the first catalyst layer and the second catalyst layer while heavy hydrocarbons in the combined feed stream are at least partially sifted in voids of the first catalyst layer, voids of the second catalyst layer, or both;

at least partially converting the sifted heavy hydrocarbons to light hydrocarbons in the first catalyst layer or the second catalyst layer in the presence of the supercritical water;

injecting purging fluid through the purging fluid inlets to contact the first catalyst layer, the second catalyst layer, or both to reduce plugging; and

passing upgraded product comprising light hydrocarbons and the converted light hydrocarbons out of the downflow supercritical upgrading reactor.

2. The process according to claim 1, where the second void volume is less than the first void volume ratio.

3. The process according to claim 1 or 2, where the purging fluid inlets are vertically disposed between the first catalyst layer and the second catalyst layer, above the first catalyst layer, or a combination of both.

4. The process according to any of the preceding claims, further comprising activating the first catalyst layer, the second catalyst layer, or both by heating at a temperature of at least 400°C.

5. The process according to any of the preceding claims, further comprising conditioning the first catalyst layer, the second catalyst layer, or both with supercritical water at the temperature and pressure of the upgrading reactor system prior to introduction of the combined feed stream.

6. The process according to any of the preceding claims, where:

the first catalyst layer and the second catalyst layer are spaced apart a distance;

the first catalyst layer, the second catalyst layer, or both comprises one or more structures selected from the group consisting of metallic honeycomb, sintered metal disk, or metallic woven cloth; and

a ratio of the first void volume ratio to the second void volume ratio is from 1 to 10.

7. A process for upgrading a petroleum-based composition comprising:

combining a supercritical water stream with a pressurized, heated petroleum-based composition in a mixing device to create a combined feed stream,

introducing the combined feed stream into an upgrading reactor system comprising one or more downflow supercritical upgrading reactors operating at a temperature greater than a critical temperature of water and a pressure greater than a critical pressure of water,

where the downflow supercritical upgrading reactor comprise at least one catalyst layer, where the at least one catalyst layer is a heterogeneous porous metal containing catalyst having a void volume ratio, and

where the downflow supercritical upgrading reactor includes at one or more purging fluid inlet disposed on one or more side locations of the downflow supercritical upgrading reactor proximate the catalyst layer;

passing the combined feed stream through the catalyst layer, where light hydrocarbons in the combined feed stream at least partially flow through the catalyst layer while heavy hydrocarbons in the combined feed stream are at least partially sifted in the voids of the catalyst layer, or both;

at least partially converting the blocked heavy hydrocarbons to light hydrocarbons in the catalyst layer in the presence of the supercritical water;

injecting purging fluid through the purging fluid inlets to contact the first catalyst layer, the second catalyst layer, or both to reduce plugging; and

passing upgraded product comprising light hydrocarbons and the converted light hydrocarbons out of the downflow supercritical upgrading reactor.

8. The process according to any of the preceding claims, where the purging fluid inlets comprise one or more linear pipes, where the one or more linear pipes

extend horizontally within the downflow supercritical upgrading reactor; or

are positioned at an angle, the angle being relative to a horizontal plane defined by the first catalyst layer.

9. The process according to any of the preceding claims, where:

the one or more purging fluid inlets comprise one or more non-linear pipes,

the non-linear pipes include at least one bend or curvature relative to a straight section of the non-linear pipe;

the bend is oriented at an angle θ relative to a plane defined by a straight section of the non-linear pipe; and

the angle θ is an acute angle, an obtuse angle, or a 90° angle.

10. The process according to any of the preceding, where the one or more purging fluid inlets comprises an annular ring having one or more openings.

11. The process according to any of the preceding claims, where:

the one or more purging fluid inlets comprise multiple pipes;

the multiple pipes are spaced apart or interconnected; and

the multiple pipes have one or more openings.

12. The process according to any of the preceding claims, where the purging fluid comprises aromatic hydrocarbons selected from the group consisting of benzene, toluene, xylene, and combinations thereof.

13. The process according to any of the preceding claims, further comprising one or more pressure sensors upstream and downstream of the downflow supercritical upgrading reactor, where the pressure sensors trigger one the purging fluid inlets to deliver purging fluid when the pressure of the downflow supercritical upgrading reactor deviates from 1%-10% of operating pressure.

14. A process for upgrading a petroleum-based composition comprising:

combining a supercritical water stream with a pressurized, heated petroleum-based composition in a mixing device to create a combined feed stream,

introducing the combined feed stream into an upgrading reactor system comprising one or more supercritical upgrading reactors and one or more supercritical standby reactors,

where the supercritical upgrading reactor and the supercritical standby reactor both operate at a temperature greater than a critical

temperature of water and a pressure greater than a critical pressure of water,

where the supercritical upgrading reactor and the supercritical standby reactor both comprise at least one catalyst layer, where the at least one catalyst layer is a heterogeneous porous metal containing catalyst having a void volume ratio, and

upgrading the combined feed stream in the supercritical upgrading reactor to produce an upgraded product;

cleaning the supercritical standby reactor by passing a cleaning fluid into the supercritical standby reactor, while the upgrading step is being performed in the supercritical upgrading reactor; and

alternating functions of the supercritical upgrading reactor and the supercritical standby reactor, such that the supercritical upgrading reactor is converted to a supercritical standby reactor undergoing a cleaning operation by the delivery of the cleaning fluid, while the supercritical standby reactor is converted to a supercritical upgrading reactor that upgrades the combined feed stream.

15. The process according to any of the preceding claims, where:

the heterogeneous porous metal containing catalyst includes one or more components selected from the group consisting of transition metals and precious metals;

the transition metals comprise one or more metal containing components comprising metals selected from the group consisting of Ti, Cr, Mn, Fe, Co, Ni, Cu, Zn, Zr, Mo, W, and combinations thereof; and

the precious metals comprise one or more metal containing components comprising metals selected from the group consisting of Au, Ag, Pt, Ro, Rh, Os, and combinations thereof.

16. The process according to claim 15, where the heterogeneous porous metal containing catalyst comprises 55 to 65 wt% Ni.

17. The process according to any of the preceding claims, where the heterogeneous porous metal containing catalyst includes at least one of metal multilayers, promoters, or alloys.

18. The process according to any of the preceding claims, further comprising one or more pressure sensors where:

the one or more pressure sensors are upstream and downstream of the supercritical upgrading reactor, the supercritical standby reactor, or both; and

the one or more pressure sensors trigger shutting down the combined feed stream from the supercritical upgrading reactor and commencing a cleaning operation.

19. The process according to claim 14, where the cleaning fluid comprises supercritical water, supercritical water and oil, or supercritical water and oxygen, where the oxygen content is between 0.1 weight percent (wt%) and 2.0 wt%.

20. A reactor for upgrading a petroleum-based composition comprising:

a first catalyst layer, a second catalyst layer disposed vertically below the first catalyst layer in the supercritical reactor, and a plurality of purging fluid inlets disposed proximate to the first catalyst layer, the second catalyst layer, or both,

where the first catalyst layer, and the second catalyst layer comprises at least a heterogeneous porous metal containing catalyst, and

where the first catalyst layer comprises a first void volume ratio, and the second catalyst layer comprises at least a second void volume ratio, and

where the at least a second void volume ratio is less than the first void volume ratio.

21. The reactor according to claim 20, where

the reactor further comprises an outermost metal tubular wall, and an insert coaxially disposed inside the metal tubular wall; and

the first catalyst layer, the second catalyst layer, and the purging fluid inlets are supported by the insert.

22. The reactor according to claim 20 or 21, where the first catalyst layer and the second catalyst layer comprise different compositions.

23. The reactor according to any of claims 20 to 22, where:

the first catalyst layer and the second catalyst layer are spaced apart a distance;

the first catalyst layer, the second catalyst layer, or both comprises one or more structures selected from the group consisting of metallic honeycomb, sintered metal disk, and metallic woven cloth; and

a ratio of the first void volume ratio to the second void volume ratio is from 1 to 10.

24. A reactor for upgrading a petroleum-based composition comprising:

at least one catalyst layer, where the at least one catalyst layer comprises a heterogeneous porous metal containing catalyst having a void volume ratio, and

at least one purging fluid inlet disposed proximate the at least one catalyst layer and configured to deliver purging fluid to the at least one catalyst layer.

25. The reactor according to claim 24, where the catalyst layer comprises one or structures selected from the group consisting of metallic honeycomb, sintered metal disk, and metallic woven cloth.

26. The reactor according to claim 24 or 25, where:

the reactor further comprises an outermost metal tubular wall and an insert coaxially disposed inside the metal tubular wall; and

the at least one catalyst layer and the at least one purging fluid inlet are supported by the insert.

27. The reactor according to any of claims 20 to 26, where:

the heterogeneous porous metal containing catalyst of the catalyst layer includes one or more components selected from the group consisting of transition metals and precious metals;

the transition metals comprise one or more metal containing components comprising metals selected from the group consisting of Ti, Cr, Mn, Fe, Co, Ni, Cu, Zn, Zr, Mo, W, and combinations thereof; and

the precious metals comprise one or more metal containing components comprising metals selected from the group consisting of Au, Ag, Pt, Ro, Rh, Os, and combinations thereof.

28. The reactor according to claim 27, where the heterogeneous porous metal containing catalyst comprises 55 to 65 wt% Ni.

29. The reactor according to any of claims 20 to 27, where the heterogeneous porous metal containing catalyst of the catalyst layer comprises at least one of metal multilayers, promoters, or alloys.

30. The reactor according to any of claims 20, 21, 24 to 27 and 29, where the purging fluid inlets comprise one or more linear pipes, where the one or more linear pipes:

extend horizontally within the downflow supercritical upgrading reactor; or

are positioned at an angle, the angle being relative to a horizontal plane defined by the first catalyst layer.

31. The reactor according to any of claims 20, 21, 24 to 27, and 29, where:

the one or more purging fluid inlets comprise one or more non-linear pipes;

the non-linear pipes including at least one bend or curvature relative to a straight section of the non-linear pipe;

the bend is oriented at an angle θ relative to a plane defined by a straight section of the non-linear pipe; and

the angle θ is an acute angle, an obtuse angle, or a 90° angle.

32. The reactor according to any of claims 20, 21, 24 to 27, and 29, where one or more purging fluid inlets comprises an annular ring having one or more openings.

33. The reactor according to any of claims 20, 21, 24 to 27, and 29, where:
one or more purging fluid inlets comprises multiple pipes;
the multiple pipes are spaced apart or interconnected; and
the multiple pipes have one or more openings.