

CLAIMS

1. A supercritical water plant to upgrade hydrocarbons with reduced coke formation, the supercritical water plant comprising:

a hydrocarbon feedstock pump, the hydrocarbon feedstock pump configured to pressurize a hydrocarbon feedstock to a pressure above the critical pressure of water to produce a pressurized hydrocarbon feedstock;

a hydrocarbon feedstock heater fluidly connected to the hydrocarbon feedstock pump, the hydrocarbon feedstock heater configured to heat the pressurized hydrocarbon feedstock to a temperature greater than 50°C to produce a heated hydrocarbon feedstock;

a feed water pump, the feed water pump configured to pressurize a feed water to a pressure above the critical pressure of water to produce a pressurized feed water;

a feed water heater fluidly connected to the feed water pump, the feed water pump configured to heat the pressurized feed water to a temperature above the critical temperature of water to produce a heated feed water;

a double-wall reactor, the double-wall reactor configured to upgrade the hydrocarbons with upgrading reactions, the double-wall reactor further configured to limit coke formation during the upgrading reactions, the double-wall reactor comprising:

a shell-side inlet fluidly connected to the feed water heater, the shell-side inlet configured to receive the heated feed water to produce a heat transfer stream in a shell-side volume;

an exterior wall and an interior wall, the exterior wall and the interior wall defining the shell-side volume disposed between, the shell-side volume configured to receive the heat transfer stream;

a reaction section volume bounded by the interior wall;

a shell-side outlet fluidly connected to the shell-side volume, the shell-side outlet configured to eject the heat transfer stream to produce a hot water return; and

a heating element, the heating element adjacent to the exterior wall, wherein the heating element is configured to heat the heat transfer stream, such that the heat transfer stream is above the critical temperature of water, wherein heat is transferred from the heat transfer stream through the interior wall to the reaction section volume;

a filter fluidly connected to the shell-side outlet, the filter configured to remove particulates from the hot water return to form a filtered water stream;

a mixer fluidly connected to the filter, the mixer configured to mix the filtered water stream and the heated hydrocarbon feedstock to produce a mixed stream, wherein the mixed stream is supplied to the reaction section volume of the double-wall reactor in a flow configuration counter-current to the heat transfer stream to produce a reaction flow stream,

wherein the reaction section volume is operable to upgrade the hydrocarbons in the reaction flow stream to produce a reactor effluent;

a reactor cooler fluidly connected to the double-wall reactor, the reactor cooler configured to cool the reactor effluent to a temperature below the critical temperature of water to produce a cooled effluent;

a pressure reducer fluidly connected to the reactor cooler, the pressure reducer configured to reduce the pressure of the cooled effluent to a pressure below the critical pressure of water to produce a depressurized effluent;

a phase separator fluidly connected to the pressure reducer, the phase separator configured to separate the depressurized effluent into a gas phase product and a liquid phase product; and

a product separator fluidly connected to the phase separator, the product separator configured to separate the liquid phase product into an upgraded hydrocarbon stream and a separated water stream.

2. The supercritical water plant of claim 1, wherein the separated water stream is combined with the feed water upstream of the feed water pump.

3. The supercritical water plant of claim 1, wherein the double-wall reactor further comprises:

a reaction inlet, the reaction inlet configured to receive the mixed stream; and

a reaction outlet, the reaction outlet configured to eject the reaction flow stream as the reactor effluent,

wherein the shell-side inlet, the shell-side outlet, the reaction inlet, and the reaction outlet are configured to create the flow configuration counter-current between the heat transfer stream and the reaction flow stream.

4. The supercritical water plant of claim 1, wherein the double-wall reactor further comprises:

baffles extending from the exterior wall into the shell-side volume, the baffles configured to increase heat transfer from the heating element and the exterior wall to the heat transfer stream.

5. The supercritical water plant of claim 1, further comprising:

a mixer pre-heater fluidly connected to the double-wall reactor, the mixer pre-heater configured to increase the temperature of the hot water return to produce a hot mixer feed, wherein the hot mixer feed is supplied to the filter to produce the filtered water stream.

6. The supercritical water plant of claim 1, further comprising:

a water super heater fluidly connected to the feed water heater, the water super heater configured to increase the temperature of the heated feed water to produce a hot water supply, wherein the hot water supply is supplied to the shell-side volume of the double-wall reactor.

7. The supercritical water plant of claim 1, further comprising:

a supercritical water reactor fluidly connected to the double-wall reactor, the supercritical water reactor configured to upgrade unreacted hydrocarbons present in the reactor effluent to produce a product stream, wherein the temperature of the supercritical water reactor is greater than the critical temperature of water, wherein the pressure of the supercritical water reactor is greater than the critical pressure of water,

wherein the product stream is supplied to the reactor cooler.

8. The supercritical water plant of claim 1, wherein a liquid yield of the upgraded hydrocarbon is greater than 98% by volume.

9. The supercritical water plant of claim 1, wherein the upgraded hydrocarbon stream has reduced amounts of asphaltene, sulfur, and other impurities relative to the hydrocarbon feedstock.

10. The supercritical water plant of claim 1, wherein a residence time of the reaction flow stream in the double-wall reactor is greater than 10 seconds.