CLAIMS

1. A method for hydrocarbon conversion in a supercritical reactor of an intimately mixed stream produced by a sequential mixer upstream of the supercritical reactor, the method comprising the steps of:

introducing a heated hydrocarbon stream to a hydrocarbon inlet of the sequential mixer, the hydrocarbon inlet parallel to a traversing axis of the sequential mixer, wherein the heated hydrocarbon stream has a pressure greater than the critical pressure of water and a temperature between 30°C. and 150°C.;

injecting a supercritical fluid through a plurality of fluid ports of the sequential mixer, wherein the plurality of fluid ports are arranged in a port alignment arrayed along the traversing axis, wherein each fluid port of the plurality of fluid ports has a port volumetric flow rate, wherein the supercritical fluid has a pressure greater than the critical pressure of water and a temperature greater than the critical temperature of water;

allowing the heated hydrocarbon stream and supercritical fluid to mix in the sequential mixer to produce an intimately mixed stream, wherein the volumetric ratio of supercritical fluid to hydrocarbons in an in-mixer stream increases as the in-mixer stream passes each of the fluid ports of the plurality of fluid ports and the in-mixer stream receives a further injection of supercritical fluid, wherein the intimately mixed stream comprises hydrocarbons and supercritical fluid, wherein the intimately mixed stream has a mixed temperature;

transferring the intimately mixed stream to a supercritical reactor, the supercritical reactor maintained at a pressure above the critical pressure of water and a temperature above the critical temperature of water, wherein the hydrocarbons in the intimately mixed stream undergo hydrocarbon conversion reactions in the supercritical reactor to produce an effluent stream;

cooling the effluent stream in a product exchanger to produce a cooled effluent, the product exchanger configured to cool the effluent stream to a temperature below the critical temperature of water to produce the cooled effluent;

depressurizing the cooled effluent in a pressure reducer to produce a product stream, the pressure reducer configured to reduce the pressure of the cooled effluent to a pressure below the critical pressure of water to produce the product stream;

separating the product stream in a gas-liquid product separator to produce a vapor phase product and a liquid phase product;

separating the liquid phase product in a liquid product separator to produce an upgraded hydrocarbon stream and a recovered fluid stream.

2. The method of claim 1, wherein the sequential mixer further comprises:

a body, the body physically connected to the hydrocarbon inlet, the hydrocarbon inlet having an inlet diameter;

a mixed stream outlet, the mixed stream outlet physically connected to the body, the mixed stream outlet having an outlet diameter;

the traversing axis, the traversing axis extending through the center of the body from the hydrocarbon inlet to the mixed stream outlet;

a cross-sectional axis, the cross-sectional axis perpendicular to the traversing axis; and

the plurality of fluid ports, the plurality of fluid ports fluidly connected to the body, wherein each fluid port has a port diameter, each fluid port has a port angle.

3. The method of claim 1, wherein the supercritical fluid is water.

4. The method of claim 1, wherein the port alignment is selected from the group consisting of straight in-line, straight across, staggered across, spiral pattern and combinations thereof.

5. The method of claim 2, wherein the port angle is between 1 deg. and 90 deg.

6. The method of claim 2, wherein the sequential mixer further comprises a flow restrictor installed between each of the plurality of fluid ports.

7. The method of claim 6, wherein the flow restrictor is an orifice place with an orifice.

8. The method of claim 1, wherein the mixed temperature is between 150°C. and 400°C.

9. A sequential mixer for mixing a heated hydrocarbon stream and a supercritical fluid to produce an intimately mixed stream upstream of a supercritical reactor, the sequential mixer comprising:

a body, the body having a body length and a body diameter;

a hydrocarbon inlet, the hydrocarbon inlet physically connected to the body, the hydrocarbon inlet having an inlet diameter, wherein the heated hydrocarbon stream is introduced to the sequential mixer through the hydrocarbon inlet;

a mixed stream outlet, the mixed stream outlet physically connected to the body and fluidly connected to the supercritical reactor, the mixed stream outlet having an outlet diameter;

a traversing axis, the traversing axis extending through the center of the body from the hydrocarbon inlet to the mixed stream outlet;

a cross-sectional axis, the cross-sectional axis perpendicular to the traversing axis; and

a plurality of fluid ports, the plurality of fluid ports physically connected to the body, wherein the plurality of fluid ports are arranged in a port alignment arrayed along the traversing axis, wherein each fluid port of the plurality of fluid ports has a port diameter, wherein each fluid port has a port angle, wherein the supercritical fluid is injected through the plurality of fluid ports.

10. The sequential mixer of claim 9, wherein the port alignment is selected from the group consisting of straight in-line, straight across, staggered across, spiral pattern and combinations thereof.

11. The sequential mixer of claim 9, wherein the port angle is between 1 deg. and 90 deg.

12. The sequential mixer of claim 9, wherein the sequential mixer further comprises a flow restrictor installed between each of the plurality of fluid ports.

13. The sequential mixer of claim 10, wherein the flow restrictor is an orifice plate with an orifice.

14. The sequential mixer of claim 9, wherein the mixed temperature is between 150°C. and 400°C.

15. The sequential mixer of claim 9, wherein the body diameter is greater than 0.1 inch.

16. The sequential mixer of claim 9, wherein the body length is greater than 0.5 inches.

17. The sequential mixer of claim 9, wherein the inlet diameter is larger than the port diameter.

18. The sequential mixer of claim 9, wherein a mixing chamber is positioned between two of the plurality of fluid ports.

19. A system for producing an upgraded hydrocarbon stream, the system comprising:

a sequential mixer, the sequential mixer configured to receive a heated hydrocarbon stream through a hydrocarbon inlet and configured to receive a supercritical fluid through a plurality of fluid ports to produce an intimately mixed stream, the intimately mixed stream comprising hydrocarbons and supercritical fluid, wherein the sequential mixer comprises:

a body, the body having a body length and a body diameter, wherein the heated hydrocarbon stream and the supercritical fluid mix in the body to produce the intimately mixed stream;

the hydrocarbon inlet physically connected to the body, the hydrocarbon inlet having an inlet diameter,

a mixed stream outlet, the mixed stream outlet physically connected to the body and fluidly connected to the supercritical reactor, the mixed stream outlet having an outlet diameter,

a traversing axis, the traversing axis extending through the center of the body from the hydrocarbon inlet to the mixed stream outlet, and

a plurality of fluid ports, the plurality of fluid ports physically connected to the body, wherein the plurality of fluid ports are arranged in a port alignment arrayed along the traversing axis, wherein each fluid port of the plurality of fluid ports has a port diameter, wherein each fluid port has a port angle, wherein the supercritical fluid is injected through the plurality of fluid ports;

a supercritical reactor, the supercritical reactor fluidly connected to the sequential mixer, the supercritical reactor configured to produce an effluent stream;

a product exchanger, the product exchanger fluidly connected to the supercritical reactor, the product exchanger configured to cool the effluent stream to a temperature below the critical temperature of water to produce a cooled effluent;

a pressure reducer, the pressure reducer fluid connected to the product exchanger, the pressure reducer configured to reduce the pressure of the cooled effluent to a pressure below the critical pressure of water to produce a product stream;

a gas-liquid product separator, the gas-liquid product separator fluidly connected to the pressure reducer, the gas-liquid product separator configured to separate the product stream to produce a vapor phase product and a liquid phase product;

a liquid product separator, the liquid product separator fluid connected to the gas-liquid separator, the liquid product separator configured to produce the upgraded hydrocarbon stream and a recovered fluid stream, wherein the upgraded hydrocarbon stream.