CLAIMS

What is claimed is:

1. A heat exchanger comprising:

    a shell having a longitudinal axis and configured to receive a first fluid;

    a plurality of baffles each mounted in the shell at a helix angle H_B to guide a first fluid flow into a helical pattern through the shell, wherein each of the plurality of baffles comprises:

        an outer circumferential edge longitudinally spaced apart from the outer circumferential edge positions of the rest of the plurality of baffles;

        a proximal radial edge spaced from a distal radial edge;

        a proximal side opposite from a distal side; and

        a plurality of spaced apart holes configured to be traversed by a plurality of axially extending tubes configured to carry a second fluid; and

    a first plurality of seal strips, each having a first end and a second end, radially disposed between the shell and the plurality of axially extending tubes and each respectively positioned between any two adjacent baffles;

    wherein each of the first plurality of seal strips is disposed to have the first end of each seal strip proximate to the distal side of a respective baffle and the second end of each seal strip proximate to the proximal side of a respective baffle at a helix angle H_s that is greater than 5° and less than the baffle helix angle H_B,

    where the helix angles H_B and H_s are defined as the angle of the respective baffle or seal strip relative to the longitudinal axis of the shell, and

    wherein each of the first plurality of seal strips have an angle greater than 0° up to 80° formed between each of the first plurality of seal strips and a line orthogonal to the proximal side of the respective baffle and the distal side of the respective baffle.

2. The heat exchanger of claim 1, wherein the seal strips, in part, are configured in part to direct a flow of fluid helically toward an outlet and in part to direct a flow of fluid away from the shell and toward the plurality of axially extending tubes.

3. The heat exchanger of claim 1, wherein:

    the first plurality of seal strips are disposed from a distal side of a first baffle from adjacent to a proximal radial edge of the first baffle to a proximal side of a second baffle adjacent to a distal radial edge of the second baffle, wherein the first and second baffles are located in a same sector or quadrant; or

    the first plurality of seal strips are disposed from a distal side of a first baffle from intermediate the proximal radial edge and distal radial edge of the first baffle to a proximal side of a second baffle intermediate a proximal radial edge and a distal radial edge of the second baffle, wherein the second baffle is located in a different sector or quadrant than the first baffle.

4. The heat exchanger of claim 1, wherein the first end of each of the first plurality of seal strips is coupled to the distal side of a first of the plurality of baffles, and wherein the second end of each of the first plurality of seal strips is coupled to the proximal side of a second of the plurality of baffles.

5. The heat exchanger of claim 1, wherein the plurality of baffles are elliptical sector-shaped baffles.

6. The heat exchanger of claim 1, wherein the first plurality of seal strips have an inner surface and an outer surface, and wherein the first plurality of seal strips are angled from the outer surface to the inner surface by an angle from orthogonal to the shell in the direction defined from a proximal radial edge to a distal radial edge of the one of the plurality of baffles.

7. The heat exchanger of claim 6, wherein each of the first plurality of seal strips is angled by 15º up to 45º from orthogonal to the shell.

8. The heat exchanger of claim 1, wherein an outer surface of each of the first plurality of seal strips is disposed proximate to an inner surface of the shell.

9. The heat exchanger of claim 1, wherein an inner surface of each of the first plurality of seal strips is spaced from an outer surface of a closest tube of the plurality of axially extending tubes by a distance that is equal to a distance between outer diameters of two adjacent tubes of the plurality of axially extending tubes.

10. The heat exchanger of claim 1, wherein each of the plurality of baffles includes at least one of the first plurality of seal strips coupled to the proximal side and at least one of the first plurality of seal strips coupled to the distal side.

11. The heat exchanger of claim 1, wherein each of the first plurality of seal strips coupled to the distal side of each of the plurality of baffles is offset rotationally about the longitudinal axis from each of the plurality of seal strips coupled to the proximal side of each of the plurality of baffles.

12. The heat exchanger of claim 1, wherein each of the first plurality of seal strips have a curved outer diameter with a curvature that is elliptical and wherein each of the first plurality of seal strips have a curved inner diameter with a curvature that is elliptical.

13. The heat exchanger of claim 1, wherein each of the first plurality of seal strips has a width, outer diameter minus inner diameter, that varies along a length, first end to second end, of the seal strip, and wherein each of the first plurality of seal strips has a depth, proximal side to distal side, that varies along the width or the length of the seal strip.

14. The heat exchanger of claim 1, wherein an equal number of seal strips of the first plurality of seal strips are coupled to each baffle of the plurality of baffles.

15. The heat exchanger of claim 1, wherein a number of seal strips of the first plurality of seal strips per rotation about the longitudinal axis of the shell is a multiple of a number of baffles per rotation about the longitudinal axis of the shell.

16. The heat exchanger of claim 1, wherein the first plurality of seal strips are formed of steel.

17. The heat exchanger of claim 1, further comprising:

a second plurality of seal strips, each having a first end and a second end radially disposed between the shell and the plurality of axially extending tubes and each respectively positioned between any two adjacent baffles,

wherein each of the second plurality of seal strips is disposed from a proximal of the plurality of baffles to a distal of the plurality of baffles at a helix angle H_{2s} that is greater than 5°, different than helix angle H_s, and less than the baffle helix angle H_B,

where the helix angles H_B, H_s, H_{2s} are defined as the angle of the respective baffle or seal strip relative to the longitudinal axis of the shell.

18. The heat exchanger of claim 1, further comprising:

a second plurality of seal strips, each having a first end and a second end radially disposed between the shell and the plurality of axially extending tubes and each respectively positioned between any two adjacent baffles,

wherein each of the second plurality of seal strips is disposed from a proximal radial edge of a baffle to a distal radial edge of the adjacent baffles.

19. The heat exchanger of claim 18, wherein an inner surface of each of the second plurality of seal strips is spaced from an outer surface of a closest tube of the plurality of axially extending tubes by a distance that is equal to a distance between outer diameters of two adjacent tubes of the plurality of axially extending tubes.

20. A method of assembling of a heat exchanger, the method comprising:

providing a center rod having a longitudinal axis;

mounting a plurality of elliptical sector-shaped baffles to the center rod at an angle to the longitudinal axis of the center rod such that a helical pattern is formed by the plurality of baffles, wherein each of the plurality of baffles comprises:

an outer circumferential edge longitudinally spaced apart from the outer circumferential edge positions of the rest of the plurality of baffles;

a proximal radial edge spaced from a distal radial edge;

a proximal side opposite from a distal side; and

a plurality of spaced apart holes;

disposing a plurality of axially extending tubes into the plurality of spaced apart holes of each of the plurality of baffles, wherein the plurality of axially extending tubes are configured to carry a second fluid;

coupling a first plurality of seal strips, each having a first end and a second end, radially between a shell and the plurality of axially extending tubes, wherein coupling the first plurality of seal strips includes:

coupling the first end of each of the first plurality of seal strips to the proximal side of one of the plurality of baffles;

coupling the second end of each of the first plurality of seal strips to the distal side of an adjacent baffle to the one of the plurality of baffles, wherein each of the first plurality of seal strips is disposed at a helix angle H_s that is greater than 5° and less than the baffle helix angle H_B,

where the helix angles H_B and H_s are defined as the angle of the respective baffle or seal strip relative to the longitudinal axis of the shell; and

angling each of the first plurality of seal strips to form an angle greater than 0° up to 80° between each of the first plurality of seal strips and a line orthogonal to the proximal side of the respective baffle and the distal side of the respective baffle; and

disposing the assembled center rod, plurality of baffles, plurality of axially extending tubes, and first plurality of seal strips within the shell that is configured to receive a first fluid.

21. The method of assembly of claim 20, wherein the coupled first plurality of seal strips have an inner surface and an outer surface, and wherein coupling the first plurality of seal strips further includes:

angling the coupled first plurality of seal strips from the outer surface to the inner surface by an angle from orthogonal to the shell in the direction defined from the proximal radial edge to the distal radial edge of the one of the plurality of baffles.

22. The method of assembly of claim 20, wherein coupling the first plurality of seal strips further includes:

spacing an inner surface of each of the first plurality of seal strips from an outer surface of a closest tube of the plurality of axially extending tubes by a distance that is equal to a distance between outer diameters of two adjacent tubes of the plurality of axially extending tubes.

23. The method of assembly of claim 20, wherein coupling the first plurality of seal strips further includes:

rotationally offsetting each of the first plurality of seal strips coupled to the distal side of each of the plurality of baffles from each of the plurality of seal strips coupled to the proximal side of each of the plurality of baffles.

24. The method of assembly of claim 20, further comprising:

coupling a second plurality of seal strips having a first end and a second end radially between the shell and the plurality of axially extending tubes, wherein coupling the second plurality of seal strips includes:

coupling the first end of each of the second plurality of seal strips to the proximal radial edge of the distal side of one of the plurality of baffles; and

coupling the second end of each of the second plurality of seal strips to the distal radial edge of the proximate side of another of the plurality of baffles,

wherein each of the second plurality of seal strips extends parallel to the longitudinal axis of the shell.

25. A heat exchanger, comprising:

a shell having a longitudinal axis and configured to receive a first fluid;

a plurality of baffles mounted in the shell at an angle to the longitudinal axis, spaced apart from each other along the longitudinal axis, and configured to guide a flow of the first fluid along a helical pattern through the shell, each of the baffles comprising:

an outer circumferential edge;

a proximal radial edge spaced from a distal radial edge;

a proximal side opposite from a distal side; and

a plurality of spaced apart holes formed through each baffle from the proximal side to the distal side, the holes configured to be traversed by a plurality of axially extending tubes with the tubes configured to carry a second fluid; and

a plurality of seal members, each comprising a first end and a second end, the seal members radially disposed between the shell and the plurality of axially extending tubes, and the first end of each seal member coupled to the distal side

of a respective baffle and the second end of each seal member coupled to the proximal side of a respective baffle,

wherein each seal member is disposed at an angle from orthogonal to the proximal side of the respective baffle, and the angle is from greater than 0° up to 80° in a direction defined from the proximal radial edge to the distal radial edge of the respective baffle.

26. The heat exchanger of claim 25, wherein the seal members comprise seal strips or seal rods.

27. A heat exchanger comprising:

a shell having a longitudinal axis and configured to receive a first fluid;

a plurality of baffles each mounted in the shell at a helix angle H_B to guide a first fluid flow into a helical pattern through the shell, wherein each of the plurality of baffles comprises:

an outer circumferential edge longitudinally spaced apart from the outer circumferential edge positions of the rest of the plurality of baffles;

a proximal radial edge spaced from a distal radial edge;

a proximal side opposite from a distal side; and

a plurality of spaced apart holes configured to be traversed by a plurality of axially extending tubes configured to carry a second fluid; and

a first plurality of circumferentially offset seal strips, each having a first end and a second end, radially disposed between the shell and the plurality of axially extending tubes and each respectively positioned between any two adjacent baffles,

wherein each of the first plurality of circumferentially offset seal strips have an angle greater than 0° up to 80° formed between each of the first plurality of circumferentially offset seal strips and a line orthogonal to the two adjacent baffles.

28. The heat exchanger of claim 27, wherein each of the plurality of baffles is connected to at least two of the first plurality of seal strips, including a distal seal strip connected to a distal side of a baffle, and a proximal seal strip connected to a proximal side of the same baffle, and wherein the proximal seal strip is circumferentially offset from the distal seal strip.

29. The heat exchanger of claim 27, wherein each of the first plurality of seal strips is parallel to a longitudinal axis of the heat exchanger.