



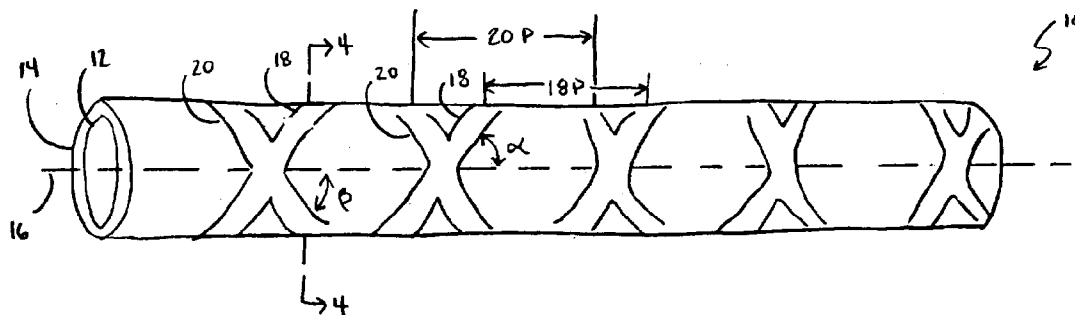
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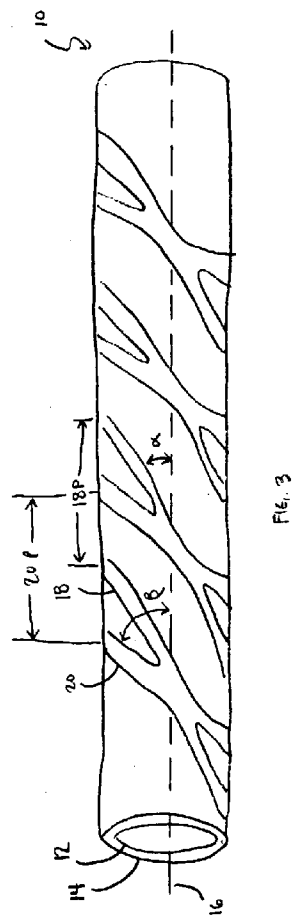
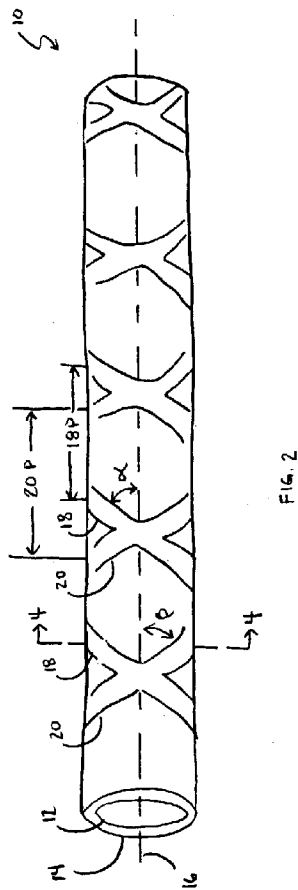
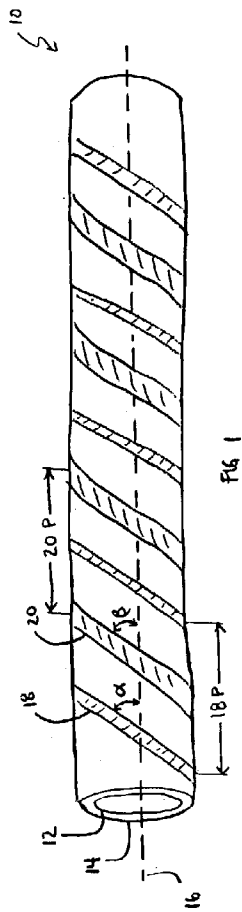
(19) **United States**(12) **Patent Application Publication**
Dilley et al.(10) **Pub. No.: US 2004/0244958 A1**(43) **Pub. Date: Dec. 9, 2004**(54) **MULTI-SPIRAL UPSET HEAT EXCHANGER
TUBE**(76) Inventors: **Roland Dilley**, Lomita, CA (US);
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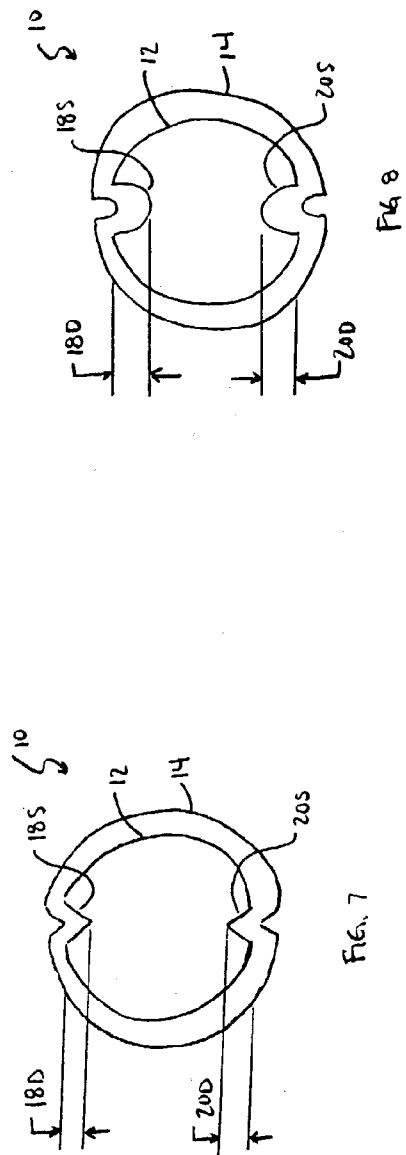
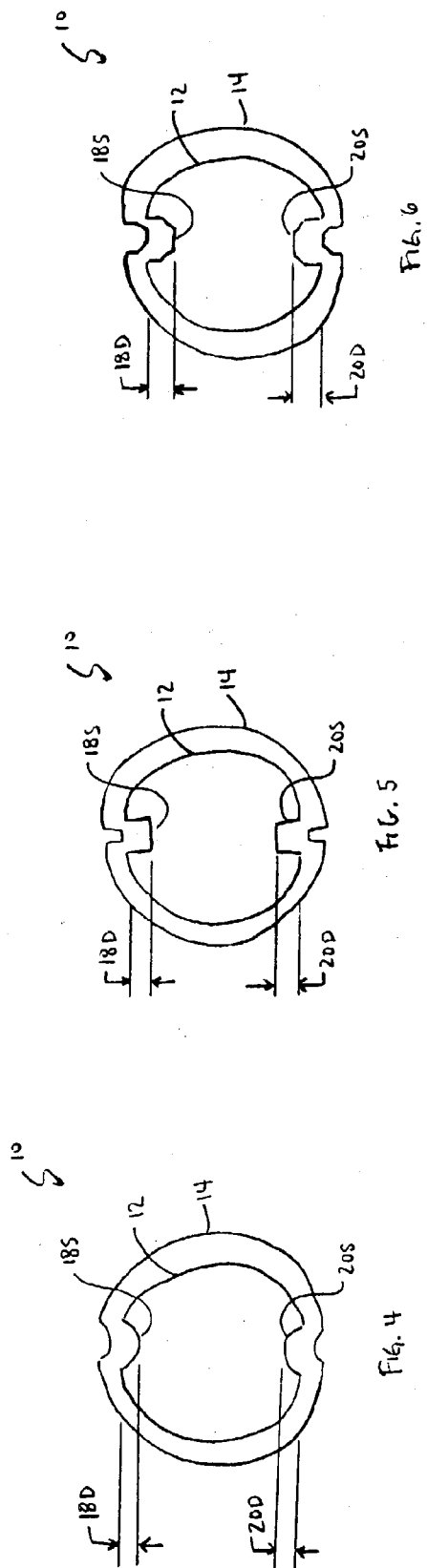
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Torrance, CA 90505 (US)(21) Appl. No.: **10/454,436**(22) Filed: **Jun. 4, 2003****Publication Classification**(51) **Int. Cl.⁷** **F28F 1/14**(52) **U.S. Cl.** **165/184; 165/179**(57) **ABSTRACT**

A heat exchanger tube is provided that includes an inner diameter, an outer diameter and a longitudinal axis. The heat exchanger includes at least two spiral upsets protruding from the inner diameter of the tube and spiraling around the longitudinal axis of a length of the tube. The at least two spiral upsets include a first spiral upset having a cross-sectional shape, a depth of protrusion from the inner diameter, a pitch, and an angle with respect to the longitudinal axis, and a second spiral upset having a cross-sectional shape, a depth of protrusion from the inner diameter, a pitch, and an angle with respect to the longitudinal axis. In one embodiment, the angle of the first spiral upset with respect to the longitudinal axis is approximately equal to the angle of the second spiral upset with respect to the longitudinal axis, such that the first and second spiral upsets are approximately parallel. In another embodiment, the absolute value of the angle of the first spiral upset with respect to the longitudinal axis is different from the absolute value of the angle of the second spiral upset with respect to the longitudinal axis, such that the first and second spiral upsets intersect at least once. A method of manufacturing a heat exchanger tube is also provided.







MULTI-SPIRAL UPSET HEAT EXCHANGER TUBE

FIELD OF THE INVENTION

[0001] The present invention relates generally to a heat exchanger tube and more particularly to a heat exchanger tube having an inner diameter, an outer diameter, a longitudinal axis and at least two spiral upsets protruding from the inner diameter of the tube and spiraling around the longitudinal axis of a length of the tube.

BACKGROUND

[0002] Heat transfer systems for cooling engine exhaust gases have traditionally required relatively small amounts of heat transfer. A typical engine exhaust gas cooling system is a shell-and-tube heat exchanger. A shell-and-tube heat exchanger includes a plurality of small diameter tubes (hereinafter heat exchanger tubes) that are encased in a larger diameter tube, providing a closed fluid flow passage. The shell-and-tube heat exchanger is a preferred engine exhaust gas cooling system because of its relatively low cost and because it provides an adequate amount of heat transfer with a relatively small amount of pressure drop in the fluid flowing therethrough.

[0003] A current heat exchanger tube for a shell-and-tube heat exchanger includes an inner diameter having a plurality of rings protruding therefrom. The rings produce turbulence in the fluid flowing through the tube, which increases the heat transfer of the tube. However, the rings produce a significant reduction in the cross-sectional area of the tube, which increases the pressure drop in the fluid flowing through the tube. Another current heat exchanger tube for a shell-and-tube heat exchanger includes an inner diameter having a single spiral protruding therefrom. The spiral produces less of a reduction in the cross-sectional area of the tube, and therefore less of a pressure drop in the fluid flowing through the tube. However, the spiral also produces less turbulence in the fluid flowing through the tube and therefore provides less heat transfer in the tube.

[0004] Accordingly, a need exists for a heat exchanger tube for a shell-and-tube heat exchanger that provides a large amount of heat transfer without significantly increasing the pressure drop of the fluid flowing through the tube.

SUMMARY

[0005] In one embodiment, the present invention is a heat exchanger tube having an inner diameter, an outer diameter and a longitudinal axis. The heat exchanger includes at least two spiral upsets protruding from the inner diameter of the tube and spiraling around the longitudinal axis of a length of the tube. The at least two spiral upsets include a first spiral upset having a cross-sectional shape, a depth of protrusion from the inner diameter, a pitch, and an angle with respect to the longitudinal axis, and a second spiral upset having a cross-sectional shape, a depth of protrusion from the inner diameter, a pitch, and an angle with respect to the longitudinal axis, wherein the angle of the first spiral upset with respect to the longitudinal axis is approximately equal to the angle of the second spiral upset with respect to the longitudinal axis, such that the first and second spiral upsets are approximately parallel.

[0006] In another embodiment, the absolute value of the angle of the first spiral upset with respect to the longitudinal

axis is different from the absolute value of the angle of the second spiral upset with respect to the longitudinal axis, such that the first and second spiral upsets intersect at least once.

[0007] In yet another embodiment, the present invention is a method of manufacturing a heat exchanger tube. The method includes providing a tube having an inner diameter, an outer diameter and a longitudinal axis. The method also includes providing at least two spiral upsets protruding from the inner diameter of the tube and spiraling around the longitudinal axis of a length of the tube. Providing the at least two spiral upsets includes providing a first spiral upset having a cross-sectional shape, a depth of protrusion from the inner diameter, a pitch, and an angle with respect to the longitudinal axis, and providing a second spiral upset having a cross-sectional shape, a depth of protrusion from the inner diameter, a pitch, and an angle with respect to the longitudinal axis, wherein the angle of the first spiral upset with respect to the longitudinal axis is approximately equal to the angle of the second spiral upset with respect to the longitudinal axis, such that the first and second spiral upsets are approximately parallel.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] These and other features and advantages of the present invention will be better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings wherein:

[0009] FIG. 1 is a perspective view of a heat exchanger tube according to one embodiment of the present invention;

[0010] FIG. 2 is a perspective view of a heat exchanger tube according to another embodiment of the present invention;

[0011] FIG. 3 is a perspective view of a heat exchanger tube according to yet another embodiment of the present invention;

[0012] FIG. 4 is a radial cross-sectional view taken from line 4-4 of FIG. 2;

[0013] FIG. 5 is a radial cross-sectional view of one embodiment of the present invention;

[0014] FIG. 6 is a radial cross-sectional view of another embodiment of the present invention;

[0015] FIG. 7 is a radial cross-sectional view of yet another embodiment of the present invention; and

[0016] FIG. 8 is a radial cross-sectional view of still another embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0017] As shown in FIGS. 1-8, embodiments of the present invention are directed to a heat exchanger tube having an inner diameter, an outer diameter, a longitudinal axis, and at least two spiral upsets protruding from the inner diameter of the tube and spiraling around the longitudinal axis of a length of the tube. The multi-spiral upset heat exchanger tube of the present invention produces turbulence in the fluid flowing therethrough rather than the rifling or swirling effect that a single spiral upset heat exchanger tube produces. In addition, the multi-spiral upset heat exchanger

tube of the present invention produces turbulence without significantly reducing the cross-sectional area of the tube as ringed heat exchanger tubes do. As a result, the multi-spiral upset heat exchanger tube of the present invention produces a large amount of heat transfer without significantly increasing the pressure drop of the fluid flowing through the tube.

[0018] FIGS. 1-3 show embodiments of a multi-spiral upset heat exchanger tube 10 according to the present invention. The tube 10 includes an inner diameter 12, an outer diameter 14 and a longitudinal axis 16. The tube 10 also includes at least two spiral upsets protruding from the inner diameter 12 of the tube 10 and spiraling around the longitudinal axis 16 of a length of the tube 10. In one embodiment, the tube 10 includes a first spiral upset 18 and a second spiral upset 20. The first spiral upset 18 includes a cross-sectional shape 18S, a depth of protrusion 18D from the inner diameter 12, a pitch 18P, and an angle with respect to the longitudinal axis 16, and second spiral upset 20 includes a cross-sectional shape 20S, a depth of protrusion 20D from the inner diameter 12, a pitch 20P, and an angle with respect to the longitudinal axis 16, wherein pitch is defined as a longitudinal distance traveled by a spiral in a single revolution.

[0019] In the embodiment depicted in FIG. 1, the angle of the first spiral upset 18 with respect to the longitudinal axis 16 is approximately equal to the angle of the second spiral upset 20 with respect to the longitudinal axis 16, such that the spiral upsets 18 and 20 are approximately parallel.

[0020] In the embodiments depicted in FIGS. 2 and 3, the angle of the first spiral upset 18 with respect to the longitudinal axis 16 is different from the angle of the second spiral upset 20 with respect to the longitudinal axis 16, such that the spiral upsets 18 and 20 intersect at least once. The angles and of the first and second spiral upsets 18 and 20 with respect to the longitudinal axis 16 may be different but have the same absolute value (as shown in FIG. 2) or the angles and may be different and have different absolute values (as shown in FIG. 3).

[0021] The spiral upsets 18 and 20 may spiral in the same direction or in opposite directions. For example, in the embodiment depicted in FIG. 2, the spiral upsets 18 and 20 spiral in opposite directions, that is the angle of the first spiral upset 18 with respect to the longitudinal axis 16 is smaller than 90°, such that the first spiral upset 18 spirals in a clockwise direction and the angle of the second spiral upset 20 with respect to the longitudinal axis 16 is larger than 90°, such that the second spiral upset 20 spirals in a counter-clockwise direction.

[0022] In the embodiments depicted in FIGS. 1 and 3, the spiral upsets 18 and 20 spiral in the same direction, that is the angles and of the spiral upsets 18 and 20, respectively, with respect to the longitudinal axis 16 are each smaller than 90°, such that the spiral upsets 18 and 20 each spiral in a clockwise direction. In another embodiment, the angles and of the spiral upsets 18 and 20, respectively, with respect to the longitudinal axis 16 are each larger than 90°, such that the spiral upsets 18 and 20 each spiral a counter-clockwise direction.

[0023] In general the closer the angles and of the spiral upsets 18 and 20 are to 90°, the greater the turbulence and pressure drop of the fluid flowing through the tube 10. The

increase in turbulence of the fluid flowing through the tube 10 increases the heat transfer of the tube 10, but also increases the pressure drop of the fluid flowing through the tube 10. As a result, in this and in other embodiments described below a trade off exists between increasing heat transfer of the tube 10 and increasing the pressure drop of the fluid flowing through the tube 10. This should be taken into account when designing the tube 10 for a specific heat transfer requirement at a specific pressure drop limit.

[0024] In any of the embodiments described above, the cross-sectional shapes 18S and 20S of the spiral upsets 18 and 20, respectively, may be different or approximately the same. FIGS. 4-8 show various appropriate cross-sectional shapes for the spiral upsets. For example, the cross-sectional shape of each spiral upset may be semi-circular (FIG. 4), semi-rectangular (FIG. 5), poly-sided such as a semi-hexagon (FIG. 6), V-shaped (FIG. 7), or U-shaped (FIG. 8), among other appropriate cross-sectional shapes.

[0025] In general, the greater the surface area of the cross-sectional shapes 18S and 20S of the spiral upsets 18 and 20, respectively, the greater the turbulence and pressure drop of the fluid flowing through the tube 10. Also, when the cross-sectional shapes 18S and 20S are different, the turbulence and pressure drop of the fluid flowing through the tube 10 are increased and in general, the greater the difference in shape and/or size of the cross-sectional shapes 18S and 20S of the spiral upsets 18 and 20, the greater the turbulence and pressure drop of the fluid flowing through the tube 10.

[0026] In any of the embodiments described above, the depths 18D and 20D of the spiral upsets 18 and 20, respectively, may be different or approximately the same. In general, the greater the depths 18D and 20D of the spiral upsets 18 and 20, the greater the turbulence and pressure drop of the fluid flowing through the tube 10. Also, when the depths 18D and 20D of the spiral upsets 18 and 20 are different, the turbulence and pressure drop of the fluid flowing through the tube 10 are increased and in general, the greater the difference in the depths 18D and 20D of the spiral upsets 18 and 20, the greater the turbulence and pressure drop of the fluid flowing through the tube 10.

[0027] In any of the embodiments above, the pitches 18P and 20P of the spiral upsets 18 and 20 may be different or approximately equal. When the pitches 18P and 20P are approximately equal, the first and second spiral upsets 18 and 20 intersect exactly once per revolution. When the pitches 18P and 20P are different, the first and second spiral upsets 18 and 20 intersect more than once per revolution. For example, when the pitch 18P of the first spiral upset 18 is twice as long as the pitch 20P of the second spiral upset 20, the first spiral upset 18 intersects the second spiral upset 20 twice per revolution. In general, the more intersections between the spiral upsets 18 and 20 per revolution, the greater the turbulence and pressure drop of the fluid flowing through the tube 10. Also in general, any change in the pitch of a spiral upset effects the angle of the spiral upset with respect to the longitudinal axis of the tube and vice versa.

[0028] As can be seen above, the number of embodiments of the multi-spiral upset heat exchanger tube 10 according to the present invention can be varied extensively by varying:

[0029] the angles and of the spiral upsets 18 and 20 with respect to the longitudinal axis 16 of the tube 10;

[0030] varying the cross-sectional shapes **18S** and **20S** of the spiral upsets **18** and **20**;

[0031] varying the depths **18D** and **20D** of the spiral upsets **18** and **20**;

[0032] varying the pitches **18P** and **20D** of the spiral upsets **18** and **20**;

[0033] providing equal or unequal angles and of the spiral upsets **18** and **20** with respect to the longitudinal axis **16** of the tube **10**;

[0034] spiraling the spiral upsets **18** and **20** in the same or opposite directions;

[0035] providing different or approximately the same cross-sectional shapes **18S** and **20S**;

[0036] providing different or approximately the same depths **18D** and **20D**;

[0037] providing different or approximately the same pitches **18P** and **20D**.

[0038] As a result, the multi-spiral upset heat exchanger tube **10** according to the present invention allows for a greater adjustability of the turbulence and pressure drop of the fluid flowing through the tube **10** than that which is provided by ringed heat exchanger tubes and single spiral heat exchanger tubes. Therefore, when a system requires a specific amount of heat transfer at a specific pressure drop limit, the variable described above can be adjusted to meet the specific given requirements.

[0039] For example, in one embodiment the tube **10** includes spiral upsets **18** and **20** that intersect at least once, have angles and with respect to the longitudinal axis **16** that are close to 90°, have depths of protrusion **18D** and **20D** that are relatively large, and have cross-sectional shapes **18S** and **20S** with relatively large surface areas. This embodiment produces a tube **10** with a relatively large amount of heat transfer. In another embodiment, the tube **10** includes spiral upsets **18** and **20** that are parallel, have angles and with respect to the longitudinal axis **16** that are close to 0°, have depths of protrusion **18D** and **20D** that are relatively small, and have cross-sectional shapes **18S** and **20S** with relatively small surface areas. This embodiment produces a tube with a relatively small amount of heat transfer.

[0040] The multi-spiral upset heat exchanger tube **10** according to the present invention may be composed of any one of a variety of materials. For example, the tube **10** may be composed of a metal material, such as stainless steel, aluminum, or copper, among other appropriate materials. In addition, the tube **10** may be manufactured by any one of a variety of methods, such as machining, casting, or extruding. For example, in a machining operation, the tube **10** may be manufactured by rotating a mandrel with respect to the tube **10** to produce spiraled grooves that form the first and second spiral upsets **18** and **20** in the tube **10**.

[0041] Although the above description and the accompanying figures describe the multi-spiral upset heat exchanger tube **10** as having two spiral upsets **18** and **20**, the tube may have any greater number of spiral upsets.

[0042] The preceding description has been presented with reference to presently preferred embodiments of the invention. Persons skilled in the art and technology to which this

invention pertains will appreciate that alterations and changes in the described structures and methods of operation can be practiced without meaningfully departing from the principle, spirit and scope of this invention. Accordingly, the foregoing description should not be read as pertaining only to the precise structures described and shown in the accompanying drawings, but rather should be read as consistent with and as support for the following claims, which are to have their fullest and fairest scope.

1. A heat exchanger tube comprising:

an inner diameter, an outer diameter and a longitudinal axis; and

at least two spiral upsets protruding from the inner diameter of the tube and spiraling around the longitudinal axis of a length of the tube, wherein the at least two spiral upsets comprise:

a first spiral upset having a cross-sectional shape, a depth of protrusion from the inner diameter, a pitch, and an angle with respect to the longitudinal axis, and

a second spiral upset having a cross-sectional shape, a depth of protrusion from the inner diameter, a pitch, and an angle with respect to the longitudinal axis, wherein the angle of the first spiral upset with respect to the longitudinal axis is approximately equal to the angle of the second spiral upset with respect to the longitudinal axis, such that the first and second spiral upsets are approximately parallel.

2. The heat exchanger tube claim 1, wherein the cross-sectional shape of the first spiral upset is approximately the same as the cross-sectional shape of the second spiral upset.

3. The heat exchanger tube claim 1, wherein the cross-sectional shape of the first spiral upset is different from the cross sectional shape of the second spiral upset.

4. The heat exchanger tube claim 1, wherein the cross-sectional shape of the first spiral upset is chosen from the group consisting of semi-circular, semi-rectangular, poly-sided, V-shaped and U-shaped and the cross-sectional shape of the second spiral upset is chosen from the group consisting of semi-circular, semi-rectangular, poly-sided, V-shaped and U-shaped.

5. The heat exchanger tube claim 1, wherein the depth of protrusion of the first spiral upset from the inner diameter of the tube is approximately equal to the depth of protrusion of the second spiral upset from the inner diameter of the tube.

6. The heat exchanger tube claim 1, wherein the depth of protrusion of the first spiral upset from the inner diameter of the tube is different from the depth of protrusion of the second spiral upset from the inner diameter of the tube.

7. The heat exchanger tube claim 1, wherein the pitch of the first spiral upset is approximately equal to the pitch of the second spiral upset.

8. The heat exchanger tube claim 1, wherein the pitch of the first spiral upset is different from the pitch of the second spiral upset.

9. The heat exchanger tube claim 1, wherein the cross-sectional shape of the first spiral upset is different from the cross-sectional shape of the second spiral upset, wherein the depth of protrusion of the first spiral upset from the inner diameter of the tube is different from the depth of protrusion of the second spiral upset from the inner diameter of the

tube, and wherein the pitch of the first spiral upset is different from the pitch of the second spiral upset.

10. A heat exchanger tube comprising:

an inner diameter, an outer diameter and a longitudinal axis; and

at least two spiral upsets protruding from the inner diameter of the tube and spiraling around the longitudinal axis of a length of the tube, wherein the at least two spiral upsets comprise:

a first spiral upset having a cross-sectional shape, a depth of protrusion from the inner diameter, a pitch, and an angle with respect to the longitudinal axis, and

a second spiral upset having a cross-sectional shape, a depth of protrusion from the inner diameter, a pitch, and an angle with respect to the longitudinal axis, wherein the absolute value of the angle of the first spiral upset with respect to the longitudinal axis is different from the absolute value of the angle of the second spiral upset with respect to the longitudinal axis, such that the first and second spiral upsets intersect at least once.

11. The heat exchanger tube claim 10, wherein the angle of the first spiral upset with respect to the longitudinal axis is smaller than 90° and the angle of the second spiral upset with respect to the longitudinal axis is larger than 90° , such that the first and second spiral upsets spiral in opposite directions, that is, the first spiral upset spirals in a clockwise direction and the second spiral upset spirals in a counter-clockwise direction.

12. The heat exchanger tube claim 10, wherein the cross-sectional shape of the first spiral upset is approximately the same as the cross-sectional shape of the second spiral upset.

13. The heat exchanger tube claim 10, wherein the cross-sectional shape of the first spiral upset is different from the cross-sectional shape of the second spiral upset.

14. The heat exchanger tube claim 10, wherein the cross-sectional shape of the first spiral upset is chosen from the group consisting of semi-circular, semi-rectangular, poly-sided, V-shaped and U-shaped and the cross-sectional shape of the second spiral upset is chosen from the group consisting of semi-circular, semi-rectangular, poly-sided, V-shaped and U-shaped.

15. The heat exchanger tube claim 10, wherein the depth of protrusion of the first spiral upset from the inner diameter

of the tube is approximately equal to the depth of protrusion of the second spiral upset from the inner diameter of the tube.

16. The heat exchanger tube claim 10, wherein the depth of protrusion of the first spiral upset from the inner diameter of the tube is different from the depth of protrusion of the second spiral upset from the inner diameter of the tube.

17. The heat exchanger tube claim 10, wherein the pitch of the first spiral upset is approximately equal to the pitch of the second spiral upset.

18. The heat exchanger tube claim 10, wherein the pitch of the first spiral upset is different from the pitch of the second spiral upset.

19. The heat exchanger tube claim 10, wherein the cross-sectional shape of the first spiral upset is different from the cross-sectional shape of the second spiral upset, wherein the depth of protrusion of the first spiral upset from the inner diameter of the tube is different from the depth of protrusion of the second spiral upset from the inner diameter of the tube, and wherein the pitch of the first spiral upset is different from the pitch of the second spiral upset.

20. A method of manufacturing a heat exchanger tube comprising:

providing a tube having an inner diameter, an outer diameter and a longitudinal axis; and

providing at least two spiral upsets protruding from the inner diameter of the tube and spiraling around the longitudinal axis of a length of the tube, wherein providing the at least two spiral upsets comprises:

providing a first spiral upset having a cross-sectional shape, a depth of protrusion from the inner diameter, a pitch, and an angle with respect to the longitudinal axis, and

providing a second spiral upset having a cross-sectional shape, a depth of protrusion from the inner diameter, a pitch, and an angle with respect to the longitudinal axis, wherein the angle of the first spiral upset with respect to the longitudinal axis is different from the angle of the second spiral upset with respect to the longitudinal axis, such that the first and second spiral upsets intersect at least once [is approximately equal to the angle of the second spiral upset with respect to the longitudinal axis, such that the first and second spiral upsets are approximately parallel].

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