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(54) **HEAT EXCHANGER AND FOLDED TUBE USED THEREIN**

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(57) **ABSTRACT**

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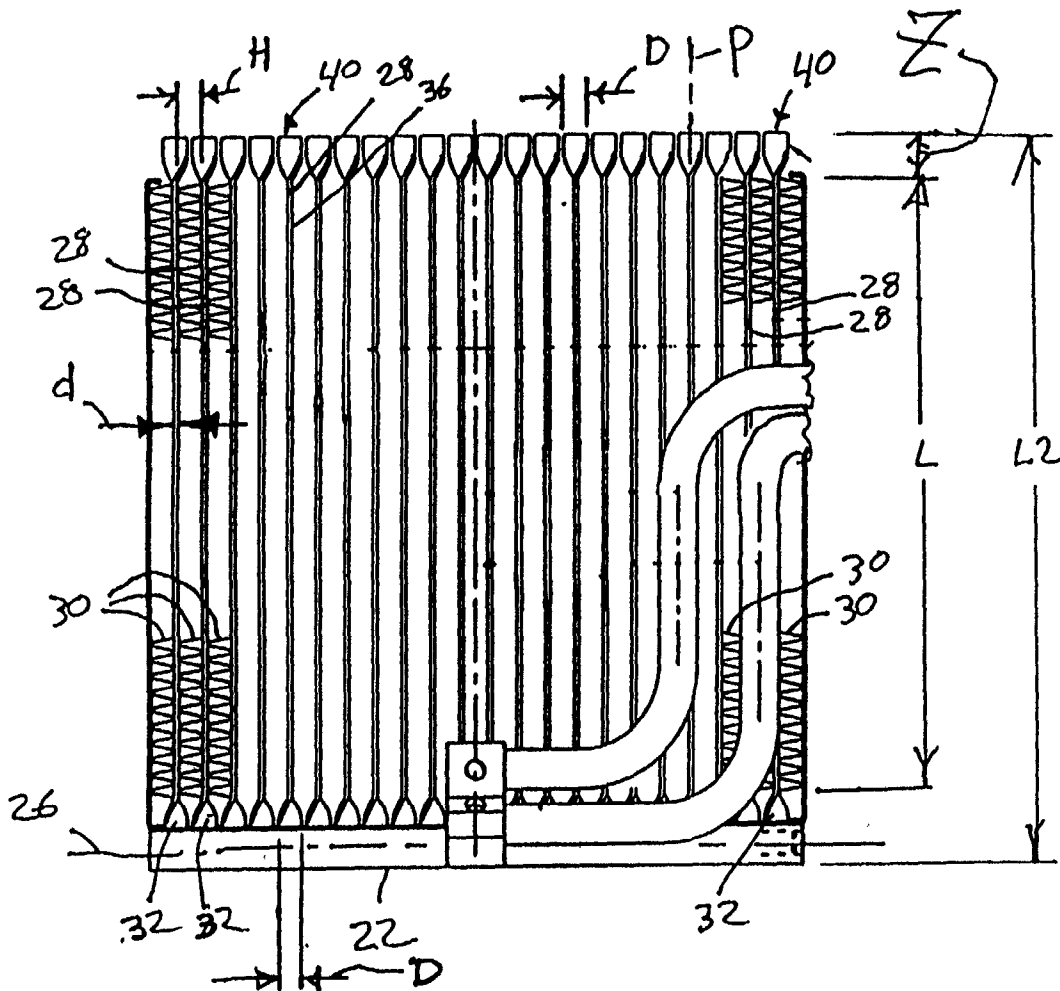
A folded, elongated tube (28) is provided for use in a heat exchanger (10, 11). The tube (28) has a flattened cross section with a minor dimension (d) and a major dimension (D). The tube (28) includes a pair of parallel tube runs (36), and a folded section (40) connecting the pair of tube runs (36). The major dimensions (D) of the tube runs (36) lie in a common plane. The folded section (40) includes a U-shaped bend (42), a first twist (44), and a second twist (46). The U-shaped bend (42) includes a straight section (48) extending between two curved sections (50, 52), and has its major dimension (D) extending substantially transverse to the major dimension (D) of the tube runs (36). The first twist (44) connects one of the tube runs (36) to the curved section (50), and the second twist (46) connects the other tube run (36) to the other curved section (52) of the U-shaped bend (42).

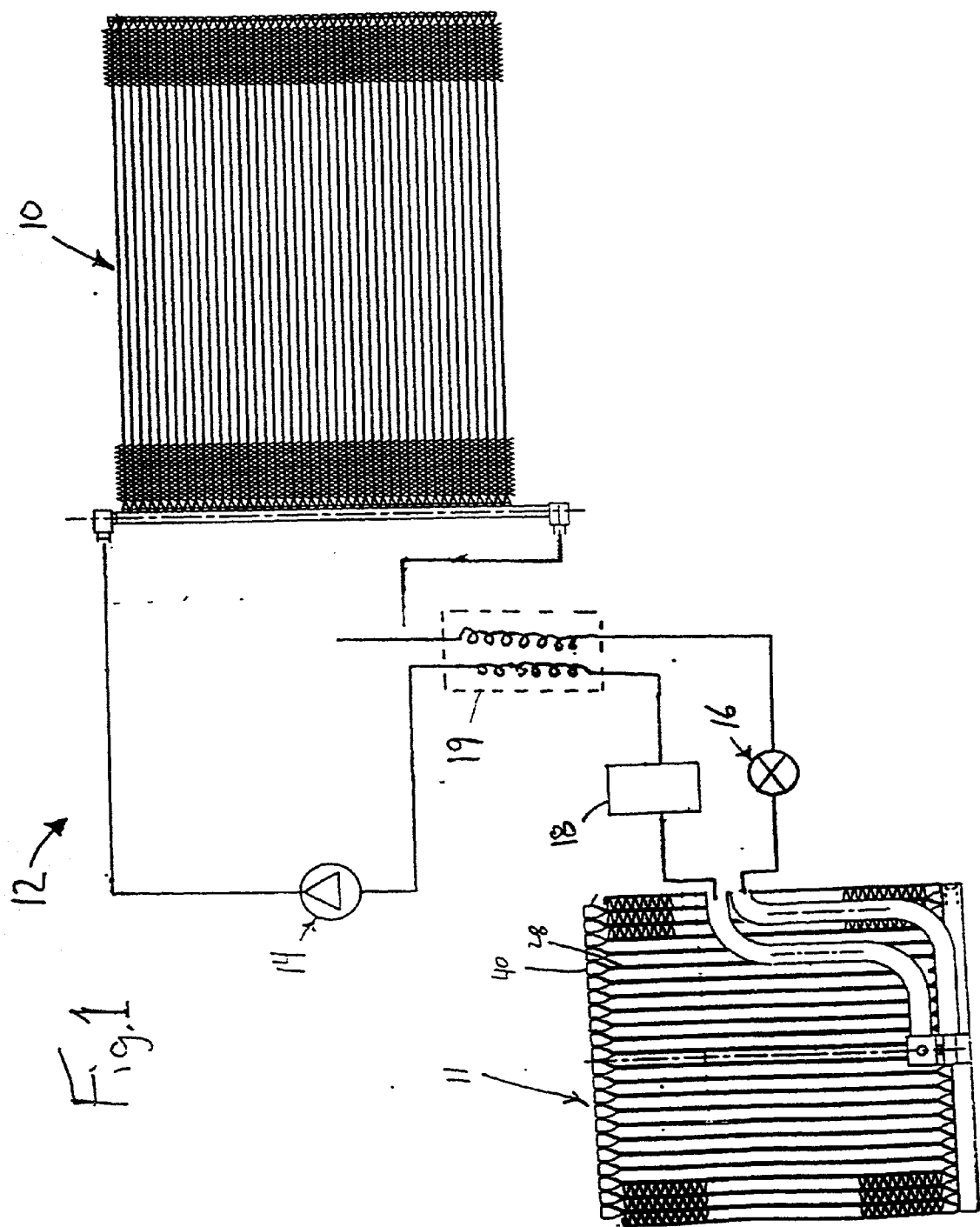
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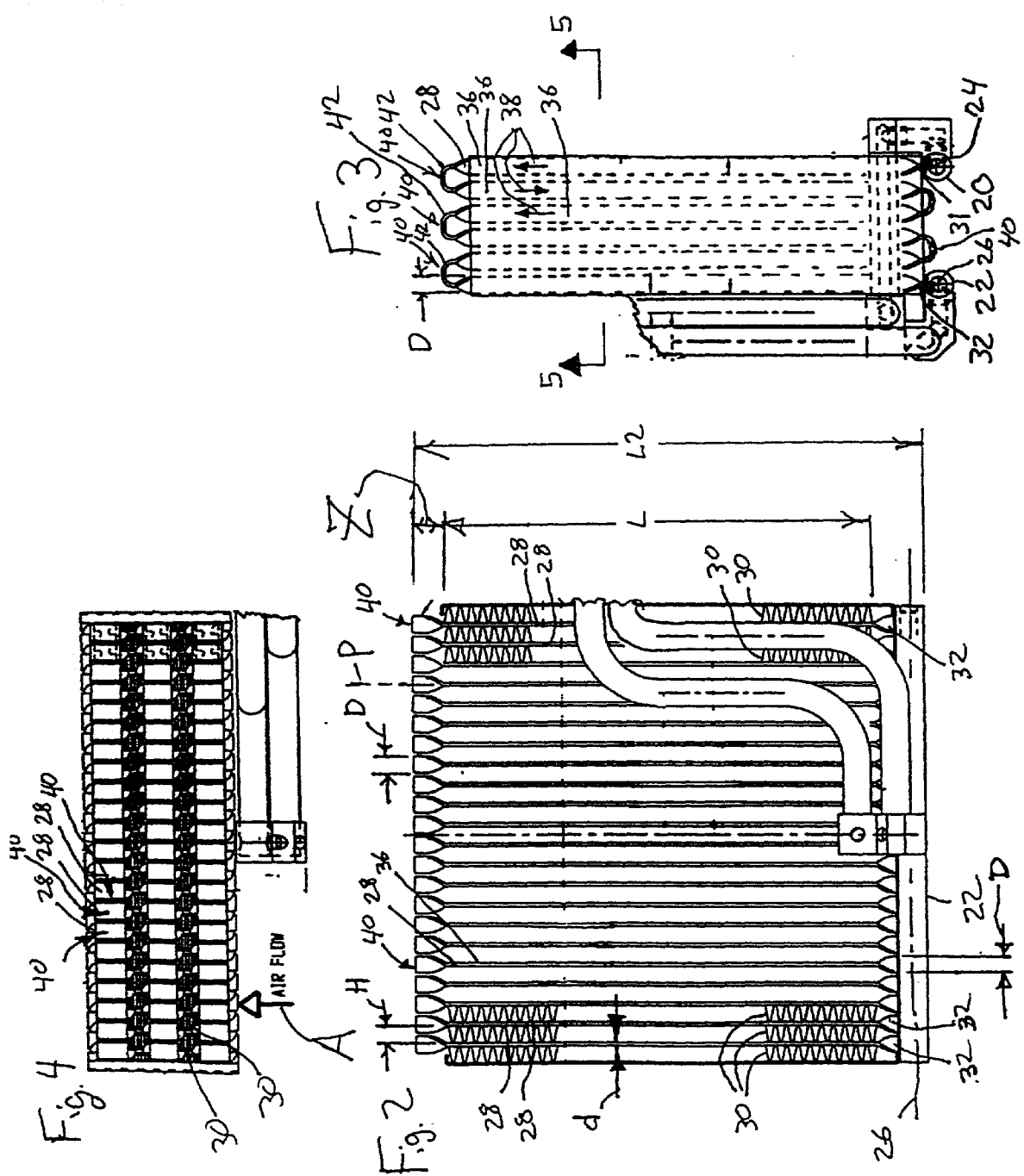
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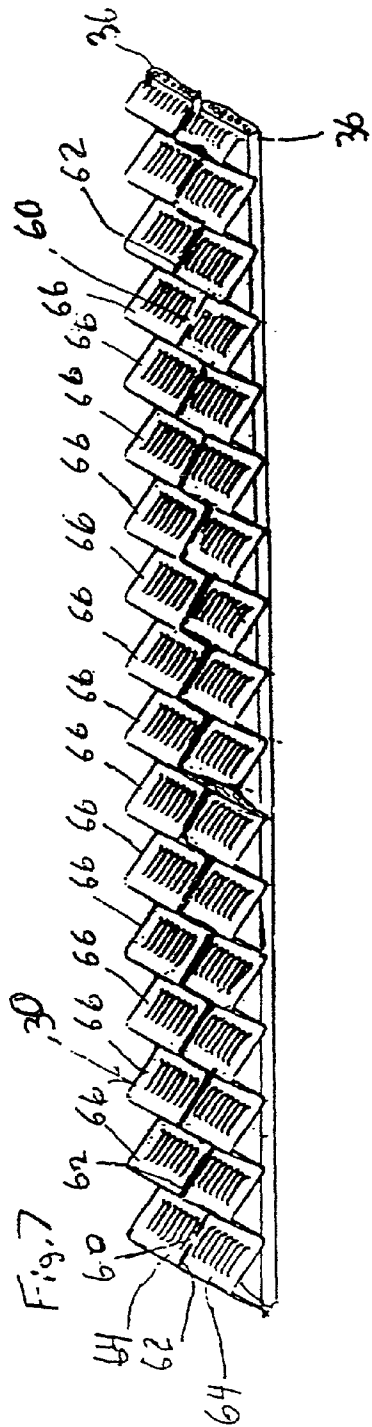
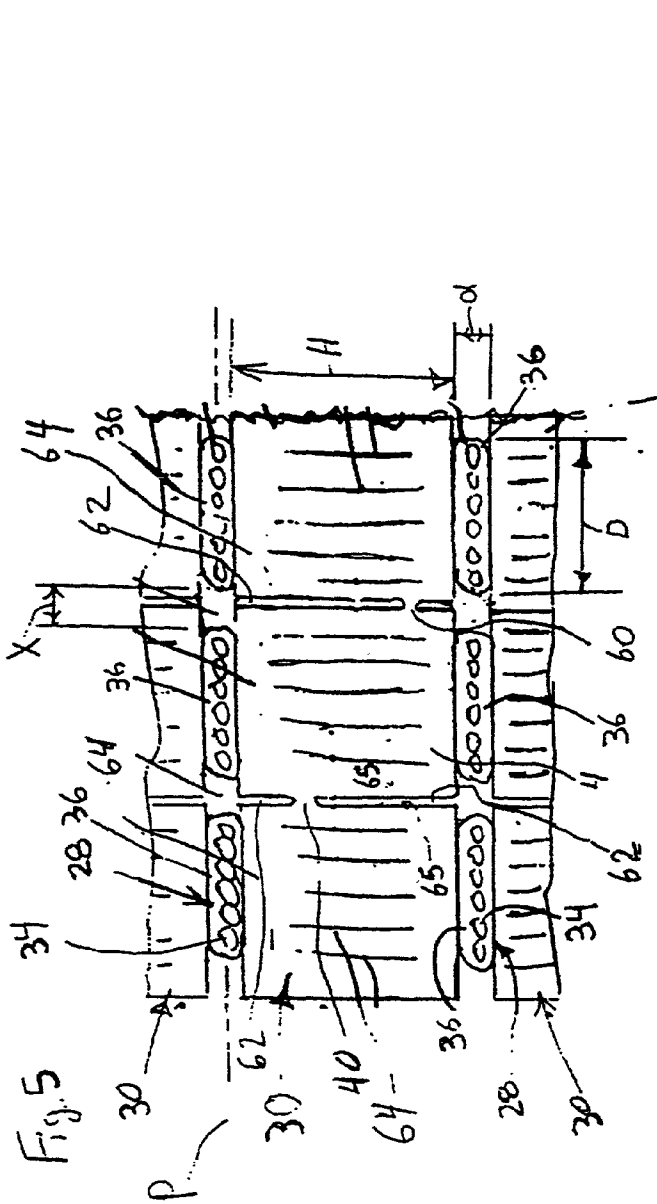
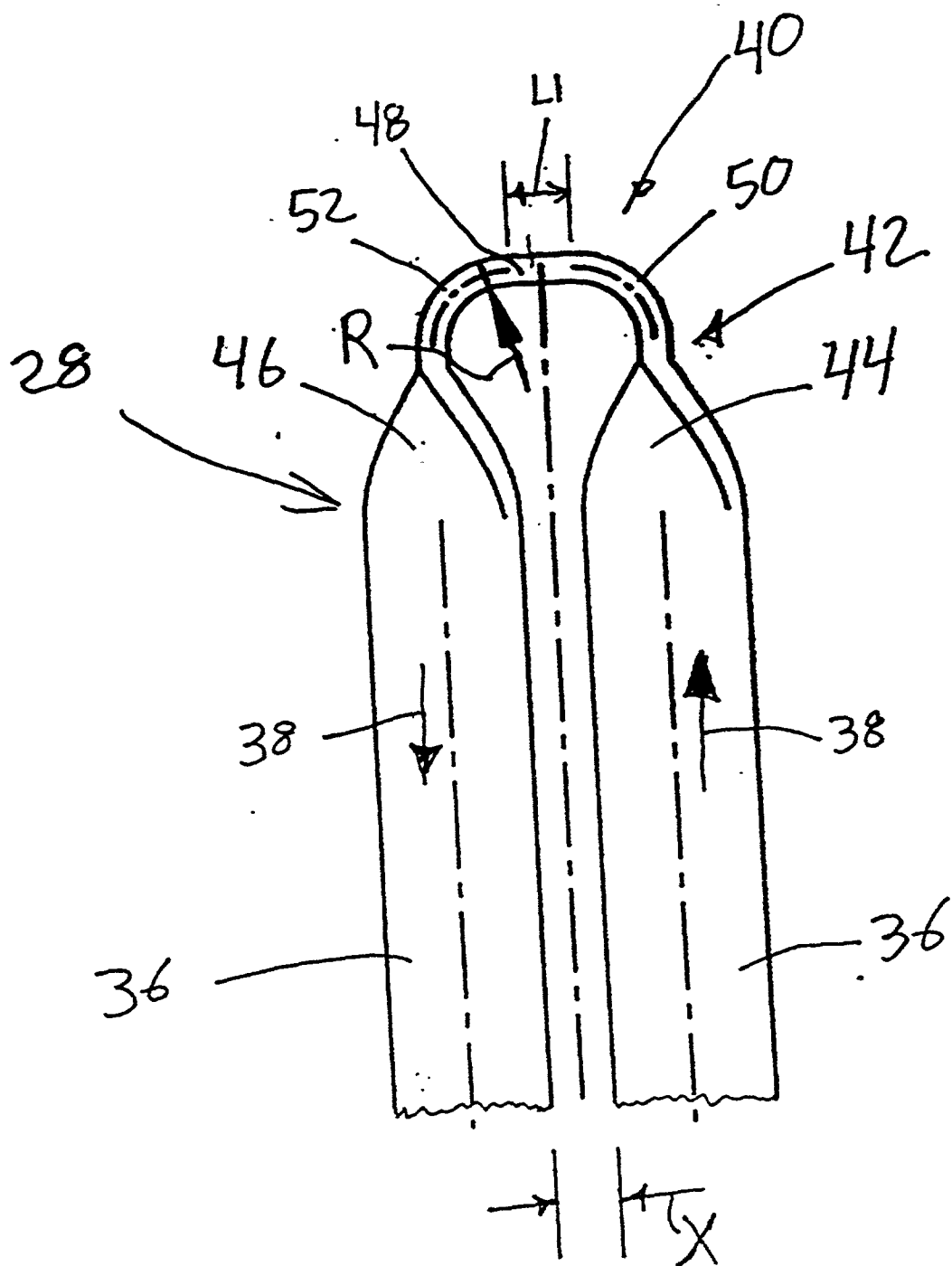
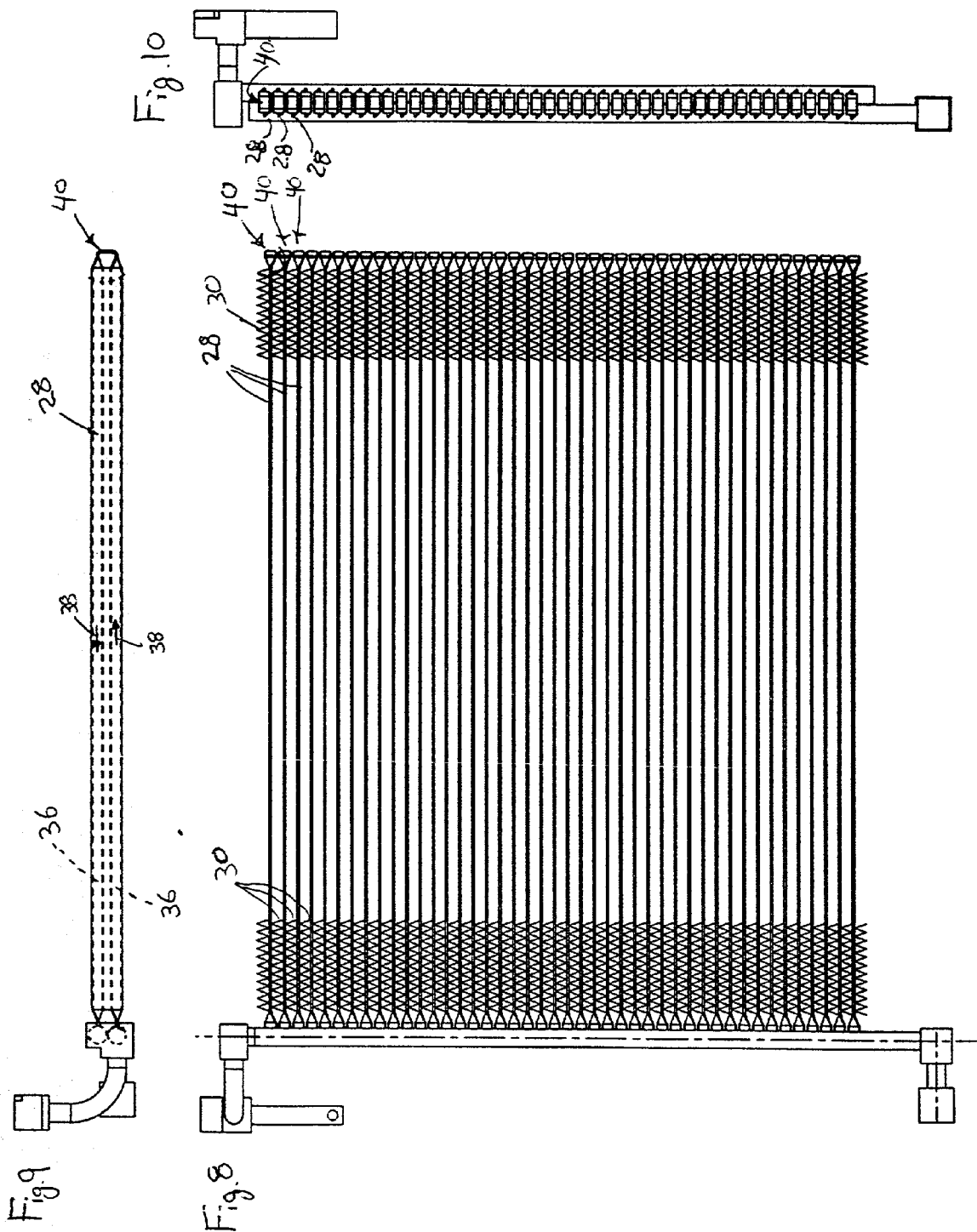


Fig. 6





HEAT EXCHANGER AND FOLDED TUBE USED THEREIN

FIELD OF THE INVENTION

[0001] This invention relates to heat exchangers and tubes therefor, and more particularly, to heat exchangers including a core made up of elongated, flat tubes and interconnecting fins.

BACKGROUND OF THE INVENTION

[0002] One common form of a heat exchanger includes a so called "core" made up of tubes and interconnecting fins. One fluid is passed through the tubes of the core while a second fluid is passed through the core itself in the spaces between the fins and tubes. Typically, the opposite ends of the tubes are connected to a pair of parallel manifolds or "tanks", with one of the manifolds being an inlet manifold and the other manifold being an outlet manifold which direct one of the fluids into and out of the tubes, respectively.

[0003] Heat exchangers of this general type are used for a large variety of purposes, such as radiators, condensers, evaporators, charge air coolers, oil coolers, etc., all of which may be utilized in a vehicle. One common form of this type of heat exchanger is known as a parallel flow heat exchanger wherein flat, multi-port tubes direct a refrigerant through the heat exchanger. Typically, the flat tubes are straight and the manifolds are spaced on opposite sides of the heat exchanger to receive the opposite ends of the tubes. However, it is known to bend the flat tubes so that the each tube is shaped as a so called "hair pin" tube having two parallel legs, with the inlet and outlet manifold positioned next to each other to receive the ends of the tubes. Examples of such a construction are shown in U.S. Pat. No. 5,531,268 issued to Hoshino et al. and EP 0 659 500 B1. While these constructions may be suitable for their intended purpose, there is always room for improvement. For example, these constructions may not be suitable or optimum for use in some air conditioning systems that rely on a higher operating pressure, such as a transcritical cooling cycle that requires a gas cooler for providing supercritical cooling of a refrigerant such as carbon dioxide (CO₂).

[0004] Increasing environmental concerns over the use of many conventional refrigerants such as CFC12 and, to a lesser extent HFC134a, has led to consideration of transcritical CO₂ systems, particularly for use in vehicular applications. For one, the CO₂ utilized as a refrigerant in such systems could be claimed from the atmosphere at the outset with the result that if it were to leak from the system back to the atmosphere, there would be no net increase in atmospheric CO₂ content. Moreover, while CO₂ is undesirable from the standpoint of a greenhouse effect, it does not affect the ozone layer and would not cause an increase in the greenhouse effect since there would be no net increase in the atmospheric CO₂ content as a result of leakage.

SUMMARY OF THE INVENTION

[0005] It is the principle object of the invention to provide a new and improved heat exchanger and tube constructions.

[0006] An exemplary embodiment of the invention achieves at least some of the foregoing objects in a heat exchanger including a pair of elongated headers having

longitudinal axes disposed substantially parallel to each other, a plurality of elongated tubes spaced in side-by-side relation along the longitudinal axes of the headers, each of the tubes having a first end connected to one of the headers and a second end connected to the other header to transfer the working fluid between the headers, and serpentine fins extending between adjacent pairs of the tubes. The tubes each have a flattened cross section with a minor dimension and a major dimension, and include a pair of parallel tube runs connected by a folded section of the tube. The major dimension of each of the tube runs extends substantially transverse to the longitudinal axes of the headers. The folded section of each of the tubes includes a U-shaped bend having a straight section of tube extending between two curved sections of tube, a first twist connecting one of the tube runs to one of the curved sections of the U-shaped bend, and a second twist connecting the other tube run to the other curved section of the U-shaped bend. Each of the U-shaped bends has its major dimension extending substantially parallel to the longitudinal axes of the headers.

[0007] In one form, the major dimension of one of the tube runs of each tube lies in common plane with the major dimension of the other tube run of the tube.

[0008] In one form, each of the twists is a 90° twist.

[0009] In one form, the major dimension of each of the tube runs extends parallel to the longitudinal axes of the headers at the location where the tube end is connected to the header.

[0010] In one form of the invention, a folded, elongated tube is provided for use in a heat exchanger. The tube has a flattened cross section with a minor dimension and a major dimension. The tube includes a pair of parallel tube runs, and a folded section connecting the pair of tube runs. The major dimensions of the tube runs lie in a common plane. The folded section includes a U-shaped bend, a first 90° twist, and a second 90° twist. The U-shaped bend includes a straight section of tube extending between two curved sections of tubes. The U-shaped bend has its major dimension extending substantially transverse to the major dimensions of the tube runs. The first 90° twist connects one of the tube runs to one of the curved sections of the U-shaped bend, and the second 90° twist connects the other tube run to the other curved section of the U-shaped bend.

[0011] In one form, the straight section of the U-shaped bend extends transverse to the parallel tube runs.

[0012] Other objects and advantages will become apparent from the following specification and claims taken in connection with the accompanying drawings.

DESCRIPTION OF THE DRAWINGS

[0013] FIG. 1 is a somewhat diagrammatic elevation view of a cooling system including a pair of heat exchangers embodying the present invention;

[0014] FIG. 2 is an elevation view of one of the heat exchangers shown in FIG. 1;

[0015] FIG. 3 is a side view of the heat exchanger shown in FIG. 2;

[0016] FIG. 4 is a top view of the heat exchanger shown in FIG. 2;

[0017] FIG. 5 is an enlarged, partial section view taken along line 5-5 in FIG. 3;

[0018] FIG. 6 is an enlarged, partial view of a tube embodying the invention and employed in the heat exchangers shown in FIG. 1;

[0019] FIG. 7 is a perspective view showing a tube and a fin utilized in the heat exchangers shown in FIG. 1;

[0020] FIG. 8 is an elevation view of the other heat exchanger shown in FIG. 1;

[0021] FIG. 9 is a top view of the heat exchanger shown in FIG. 8; and

[0022] FIG. 10 is a side view of the heat exchanger shown in FIG. 8.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0023] Referring to FIG. 1, heat exchangers 10 and 11 embodying the present invention are shown in connection with a cooling system 12 that operates a transcritical cooling cycle. The heat exchanger 10 is shown in the form of a gas cooler that provides supercritical cooling to the working fluid or refrigerant, such as CO₂, of the cooling system 12 by rejecting heat to a medium, such as an air flow, on the fin side of the heat exchanger 10. The heat exchanger 11 is shown in the form of an evaporator that transfers heat from one medium, such as an airflow on the fin side of the heat exchanger 11 to the refrigerant in the system 12 to change the refrigerant from the liquid phase to the gaseous phase. The cooling system 12 further includes a compressor 14 that compresses gaseous phase refrigerant to a supercritical pressure for delivery to the heat exchanger 10, an expansion device 16 that reduces the pressure in the refrigerant received from the heat exchanger 10 so at least some of the refrigerant enters the liquid phase, an accumulator 18 (optional), and a suction line heat exchanger 19 that transfers heat from the refrigerant exiting the gas cooler 10 to the refrigerant exiting the evaporator 11, or accumulator 18 if used. While the heat exchangers 10 and 11 are shown in connection with a transcritical cooling cycle, it should be understood that the heat exchangers 10 and 11 may find uses in other types of cooling and/or heating systems, and in other configuration of cooling systems that perform a transcritical cooling cycle, and are not limited to use with the specific cooling system shown in FIG. 1 unless specifically recited in the claims. Further, it should be understood that the heat exchangers 10 and 11 can be adapted for a large variety of purposes, such as for use as radiators, condensers, charge air coolers, oil coolers, etc.

[0024] Having described a typical operating environment for the heat exchangers 10 and 11, a more detailed description will now be provided for the heat exchangers 10 and 11, with a focus on the heat exchanger 11 for the purpose of brevity.

[0025] With reference to FIGS. 2-4, the heat exchanger 11 includes a pair of elongated tubular headers 20 and 22 having longitudinal axes 24 and 26, respectively, disposed substantially parallel to each other; a plurality of elongated tubes 28 spaced in side-by-side relation along the longitudinal axes 24, 26 of the headers 20, 22; and serpentine fins 30 extending between adjacent pairs of the tubes 28. It

should be understood that in the illustrated embodiment, each fin 30 extends over a length L of the tubes 28, but the middle portions of the lengths are not shown in FIG. 2 for convenience of illustration. Preferably, the fins 30 are louvered. As seen in FIG. 3, each of the tubes 28 has a first end 31 connected to the header 20, and a second end 32 connected to the header 22 to transfer the refrigerant between the headers 20, 22.

[0026] Each of the tubes 28 has a flattened cross-section with a major dimension D and a minor dimension d, as best seen in FIG. 5. Each of the tubes 28 is preferably a multi-port tube. In this regard, it should be understood that while FIG. 5 shows six ports 34, it may be beneficial in some applications to include more than, or less than, six ports 34 in each of the multi-port tubes 28. For example, in one preferred embodiment each of the tubes has four ports 34. Additionally, it should be understood that the hydraulic diameter of the tubes 28 will be highly dependent upon the specific parameters of each particular application, such as, for example, of the particular working fluid used within the heat exchanger and the flow rate of the working fluid to the heat exchanger.

[0027] In one preferred embodiment, the tubes are configured to withstand a burst pressure of at least 6500 PSI, such as may be required for a heat exchanger in a transcritical CO₂ cooling system. Further, in some preferred embodiments for use in a transcritical CO₂ cooling system, the hydraulic diameter of the tube is preferably in the range of 0.015 inch to 0.045 inch, the major dimension D of each of the tubes 28 is preferably no greater than 0.500 inch, and the minor dimension d is preferably no greater than 0.100 inch, while in some highly preferred embodiments the minor dimension d is nominally no greater than 0.060 inch and the major dimension D is nominally no greater than 0.320 inch.

[0028] As best seen in FIGS. 3 and 6, each of the tubes 28 is folded upon itself to define at least two parallel tube runs 36 of the tube 28 so that the refrigerant flows serially through at least two parallel fluid passes 38 from the header 20 to the header 22. In this regard, it is preferred that the inlet and outlet headers 20, 22 be selected so that the heat exchanger 11 operates in a cross-counterflow configuration relative to the fluid flow A on the fin side of the heat exchanger 11. Each pair of the parallel tube runs 36 is joined by a fold 40 that is twisted 90° relative to the tube runs 36 at the location of the fold 40 so that the major dimension D extends parallel to the axes 26, 24 at the location of the fold 39, rather than transverse.

[0029] As best seen in FIG. 6, each of the folds 40 includes a U-shaped bend 42, a first 90° twist 44, and a second 90° twist 46. Each U-shaped bend 42 includes a straight section 48 extending between two curved sections 50 and 52. The twist 44 connects one of the tube runs 36 to one of the curved sections 50, and the twist 46 connects the other parallel tube run 36 to the other curved section 52.

[0030] Preferably, the fold 40 is formed by first twisting the tube runs 36 90° relative to the portion of the tube 28 that will form the straight section 48 and then bending the tube 28 at each end of the straight section 48 through approximately 90° to form the curved sections 50 and 52. In this regard, it should be understood that the 90° twist of each of the tube runs 36 relative to the fold 40 can be in the same direction as shown in FIGS. 3 and 6, or in opposite

directions, depending upon which configuration offers the most advantage for a particular application of the heat exchanger 11.

[0031] As best seen in FIG. 6, the parallel tube runs 36 of each of the tubes 28 are preferably spaced from each other by a distance X, with the major dimension D of each of the parallel tubes 36 lying in a common plane, illustrated by dashed line P in FIGS. 2 and 5, that is substantially transverse to the longitudinal axes 24, 26 of the headers 20, 22. This allows the major dimension D to extend parallel to the direction A of the flow of the medium through the fins 30. The spacing X reduces heat conduction from one tube run 36 to the other, which can be advantageous when the heat exchanger 10 is providing supercritical cooling because the temperature of the refrigerant can vary substantially as it flows through the tube 28 from one header 20 to the other header 22. Preferably, the distance X is sufficient to minimize or prevent the closing of the space between adjacent parallel tube runs 36 by braze material during brazing of the heat exchanger 10, but not so large so as to unduly increase the depth of the heat exchanger 10. While it is preferred that the adjacent parallel tube 36 of each tube 28 be spaced from each other, in some applications this spacing may not be required and/or desirable.

[0032] In one preferred embodiment, the straight section 48 of each of the tubes 28 has a length L1 that at least doubles the minor dimension of the flattened tube cross section. However, it should be appreciated that the length L1 of the straight section 48 can vary from application to application depending upon the particular parameters of each application, such as, for example, the acceptable bend radius R for the curved sections 50 and 52 of the bends 42 and the desired spacing X between each of the tube runs 36.

[0033] As best seen in FIG. 3, the illustrated heat exchanger 11 includes 6 parallel tube runs 36 for each of the tubes 28. However, it should be understood that the optimum number of parallel tube runs for each application of the heat exchanger 10 will be highly dependent upon the specific parameter for the particular application such as, for example, the working fluid of the system 12, the envelope and environment into which the heat exchanger 11 must be packaged, and the function of the heat exchanger, i.e. as a gas cooler, condenser, or evaporator for use in an AC or heat pump system. For example, in some applications it may be desirable to have as few as two or three parallel tube runs 36 for each of the tubes 28, or 12 or more tube runs 36 for each of the tubes 28. By way of further example, FIGS. 8, 9 and 10 show the heat exchanger 10 having two parallel tube runs 36 for each of the tubes 28.

[0034] As seen in FIGS. 1 and 5, each of the fins 30 has a fin height H equal to the spacing between adjacent tubes 28, i.e. a fin height H extending from one of the tubes 28 to an adjacent tube 28 parallel to the longitudinal axes 24, 26 of the headers 20, 22. Preferably, the major dimension D of the tubes 28 is either no greater than the fin height H, or no greater than the sum of the fin height H and the minor dimension d. This allows a construction wherein each of the tube ends 31, 32 can be twisted 90° relative to the parallel tube runs 36 from which they extend so that the major dimension D of the ends 31, 32 extends parallel to the longitudinal axes 24, 26 of the headers 20, 22 at the location where the tube ends 31 and 32 are connected to the headers

20 and 22, as seen in FIG. 2. This can be important in high pressure applications, such as heat exchangers used in transcritical refrigeration systems, where it is desirable that the diameter of the headers 20, 22 be as small as possible. It is conceivable, even likely, in such constructions that the major dimension D will be greater than the inner diameter of either of the headers 20, 22. By allowing the major dimension D to extend parallel to the longitudinal axis 24, 26 of the headers 20, 22 where the tube ends 31, 32 are connected to the headers 20, 22, the major dimension D of each of the tubes 28 can be greater than the inner diameter of either of the headers 20, 22.

[0035] As previously discussed, each of the serpentine fins 30 has a length L extending parallel to the parallel tube runs 36 of the adjacent tubes 28, and as best seen in FIG. 4, a transverse width W extending across the parallel tube runs 36 of the adjacent tubes 28. For purposes of illustration, FIG. 5 shows three tube runs 36 of the tubes 28 and FIG. 7 shows a fin 30 for use with a heat exchanger construction 10 wherein each of the tubes 28 has only two parallel runs 36. With reference to FIG. 7, each of the fins 30 includes a plurality of alternating tabs 60 and elongated separations 62 extending parallel to the parallel tube runs 36 and located between the parallel tube runs 36 of the adjacent tubes 28 to divide the width W of each fin 30 into two or more discrete fin strips or elements 64 that are connected to each other by the tabs 60. Each of the fin elements 64 corresponds to and extends along one of the parallel tube runs 36 of each of the adjacent tubes 28. The separations 62 are generally straight line and have opposed edges 65 that face one another and are generally transverse to the direction of the medium flow through the fins 30. While FIG. 7 illustrates the fin 30 for tubes 28 having two parallel tube runs 36, it should be understood that the above construction including the tabs 60, separations 62 and fin elements 64 is utilized in constructions of the heat exchanger 10 having more than two parallel tube runs 36 in each of the tubes 28, such as the constructions shown in FIGS. 2-5. In such constructions, each of the fins 30 preferably extends across all of the parallel tube runs 36 with a fin element 64 corresponding to and extending along each of the parallel tube runs 36 of each of the adjacent tubes 28, and the tabs 60 and separations 62 provided between each of the fin elements 64.

[0036] The alternating tabs 60 in each of the fins 30 serve to restrict movement of the fin elements 64 relative to each other so that each fin 30 remains a unitary component during the assembly of the heat exchanger 10 and, furthermore, to better maintain the fin elements 64 in alignment with each other to minimize the pressure drop on the fin side of the heat exchanger. The purpose of the elongated separations 62 is to minimize the heat conduction from each of the parallel tube runs 36 to any adjacent parallel tube runs 36 of each tube 28 by interrupting, and thus minimizing, the heat conduction between the fin elements 64 associated with each of the parallel legs 36. Thus, it is desirable for each of the elongated separations 62 to extend uninterrupted as far as possible along the length of the fin 30 and for the number and size of the tabs 60 to be minimized to that which is required to prevent each of the fin elements 64 from separating during assembly and to maintain an acceptable degree of alignment between the fin elements 64 of each of the fins 30 during assembly.

[0037] From the foregoing, it should be understood that a number of configurations are possible for the tabs 60 and the elongated separations 62. For example, in one embodiment of a fin 30 made of aluminum, with the fin 30 in an unfolded state, each of the tabs 60 extends approximately 0.020 inch along the length of the unfolded fin 30 and each of the elongated separations 62 of a fin 30 extends approximately 8.0 inches along the length of the unfolded fin 30. In one preferred embodiment of the fin 30, the tabs 60 and the separations 62 have lengths extending parallel with the length of the fin 30 in the unfolded state, and the ratio of the length of the separations 62 to the length of the tabs 60 is in the range of 200 to 600. In another example, such as shown in FIG. 7, each of the elongated separations 62 extends uninterrupted from one of the tabs 60 over 10 to 14 of the folds 66 to the next tab 60 with the fin 30 in the folded condition.

[0038] While the tabs 60 and the separations 62 can be formed in a number of ways, it is preferred that the separations 62 be formed as cuts or slits in the fin material that do not require removal of fin material during formation in the fin 30. One way of achieving such slits or cuts is to use a splitter disk in the fin roll die to create a simple cut in the fin 30 as the fin 30 is formed from a strip of sheet material. The split can be eliminated for a small portion of the disk in every revolution to form the tabs 60 to ensure that each fin element 64 stays attached to the adjoining fin element 64 of the fin 30. This provides a physical cut or slit in the fin 30, with no loss of fin surface. In one such construction, the edges 65 are virtually, but not quite, in abutment with each other. One concern is that the fin elements 64 might braze together during the brazing process. One approach to minimize this concern is to locate the braze material on the side walls of the tube runs 36 that abut the fins 30, rather than cladding the braze material onto the fins 30. Another approach to minimize this concern is to offset adjacent fin elements 64 of the fin 30 at locations remote from the tab 60, which may allow for clad fins. Another approach would be to bend the edges 65 formed by the slits slightly apart, forming a very small louver, which may also allow for clad fins. Yet another approach is to coin each of the tab portions 60 to further separate the fin elements 64 from each other. Again, this last approach may allow for clad fins. While slits are preferred, in some applications it may be advantageous for the separations 62 to be formed as slots that do require removal of fin material when formed in the fins 30. In this regard, it would probably be sufficient for the slots to have a width of a few thousands of an inch parallel to the width W of the fin 30.

[0039] While it is preferred that the fins 30 include the tabs 60 and separations 62, in some applications the tabs 60 and separations 62 may not be desirable and/or required.

[0040] It is preferred that the fins 30 be louvered, many forms of which are known. The exact configuration of the louvers will be highly dependent on the parameters of the particular application such as, for example, the fluid on the fin side of the heat exchanger 10, the available pressure drop on the fin side of the heat exchanger 10, the number of parallel tube runs 36 in each of the tubes 28, and whether there is an odd or even number of parallel tube runs 36 in each of the tubes 28.

[0041] In one preferred embodiment the headers 20, 22, tubes 28, and fins 30 are all made of aluminum and brazed

with an appropriate braze material. However, it should be understood that in some applications other suitable materials made be employed for these components as dictated by the parameters of the particular application.

[0042] It should also be understood that while the heat exchanger 11 illustrated in FIGS. 1-3 is shown so that the longitudinal axes 24, 26 of the headers 20, 22 extend in a horizontal direction, and the parallel tube runs 36 of the tubes 28 extend in a vertical direction, it may be desirable in some applications for a heat exchanger 11 to have a different orientation, such as, for example, an orientation wherein the axes 24, 26 extend in a vertical direction and the parallel tube runs 36 extend in a horizontal direction. Further, while the headers 20, 22 of the heat exchanger 11 illustrated in FIGS. 1-3 are located on the same side of the heat exchanger 11, it may be desirable in some applications for the headers 20, 22 to be located on opposite sides of the heat exchanger 11. A construction with the headers 20, 22 on the same side of the heat exchanger will typically result in an even number of parallel tube runs 36 for each of the tubes 28, while a construction with the headers 20, 22 on opposite sides of the heat exchanger 10 will typically result in an odd number of parallel tube runs 36 for each of the tubes 28. Of course, header plates fitted with tanks could be employed in lieu of the tubular headers 20, 22 if desired for a particular application.

[0043] It should be appreciated that by providing the straight section 48 in the U-shaped bend 42, the dimension L2 of the heat exchanger is minimized, as well as the portion Z of the tubes 28 that are not provided with fins 30.

1. A heat exchanger comprising:

- a pair of elongated headers having longitudinal axes disposed substantially parallel to each other;
- a plurality of elongated tubes spaced in side by side relation along the longitudinal axes of the headers, each of the tubes having a first end connected to one of the headers and a second end connected to the other header to transfer the working fluid between the headers, each of the tubes having a flattened cross section with a minor dimension and a major dimension, each of the tubes including a pair of parallel tube runs connected by a folded section of the tube, the major dimension of each of the tube runs extending substantially transverse to the longitudinal axes of the headers, the folded section of each of the tubes comprising
 - a U-shaped bend including a straight section of tube extending between two curved sections of tube, the bend having its major dimension extending substantially parallel to the longitudinal axes of the headers,
 - a first twist connecting one of the tube runs to one of the curved sections of the U-shaped bend, and
 - a second twist connecting the other tube run to the other curved section of the U-shaped bend; and
- serpentine fins extending between adjacent pairs of said tubes.

2. The heat exchanger of claim 1 wherein for the major dimension of one of the tube runs of each tube lies in a common plane with the major dimension of the other tube run of the tube.

3. The heat exchanger of claim 1 wherein the straight section of each of the U-shaped bends extends transverse to the parallel legs.

4. The heat exchanger of claim 1 wherein each of the twists is a 90° twist.

5. The heat exchanger of claim 1 wherein each of the tubes further comprises:

a third tube run parallel to the pair of tube runs, the major dimension of the tube extending transverse to the longitudinal axes of the headers; and

a second folded section of tube connecting the third tube run to one of the other tube runs of the tube, the second folded section comprising

a second U-shaped bend including a straight section of tube extending between two curved sections of tube and having its major dimension extending substantially parallel to the longitudinal axes of the headers,

a third twist connecting the one of the other tube runs to one of the curved sections of the second U-shaped bend, and

a fourth twist connecting the third tube run to other curved section of the second U-shaped bend.

6. The heat exchanger of claim 1 wherein the straight section of each of the tubes has a length that at least doubles the minor dimension of the flattened tube cross section.

7. The heat exchanger of claim 1 wherein the parallel legs of each of the tubes are spaced from each other.

8. The heat exchanger of claim 1 wherein the major dimension of each of the tube ends extends parallel to the longitudinal axes of the headers at the location where the tube end is connected to the header.

9. The heat exchanger of claim 1 wherein one of the twists of each of the tubes is a left handed twist and the other twist of the tube is a right handed twist.

10. The heat exchanger of claim 1 wherein one of the twists of each of the tubes is a left handed twist and the other twist of the tube is a left handed twist.

11. The heat exchanger of claim 1 wherein one of the twists of each of the tubes is a right handed twist and the other twist of the tube is a right handed twist.

12. A folded, elongated tube for use in a heat exchanger, the tube having a flattened cross section with a minor dimension and a major dimension, the tube comprising:

a pair of parallel tube runs, the major dimensions of the tube runs lying in a common plane; and

a folded section of tube connecting the pair of tube runs, the folded section comprising

a U-shaped bend including a straight section of tube extending between two curved sections of tube and having its major dimension extending substantially transverse to the major dimensions of the tube runs,

a first 90° twist connecting one of the tube runs to one of the curved sections of the U-shaped bend, and

a second 90° twist connecting the other tube run to the other curved section of the U-shaped bend.

13. The tube of claim 12 wherein the straight section of the tube has a length that at least doubles the minor dimension of the flattened tube cross section.

14. The tube of claim 12 wherein the straight section of the U-shaped bend extends transverse to the parallel legs.

15. The tube of claim 12 further comprising:

a third tube run parallel to the pair of tube runs, the major dimension of the tube run lying in the common plane; and

a second folded section of tube connecting the third tube run to one of the other tube runs, the second folded section comprising

a second U-shaped bend including a straight section of tube extending between two curved sections of tube and having its major dimension extending substantially transverse to the major dimensions of the tube runs,

a third 90° twist connecting the one of the other tube runs to one of the curved sections of the second U-shaped bend, and

a fourth 90° twist connecting the third tube run to other curved section of the second U-shaped bend.

16. The tube of claim 12 wherein the parallel legs are spaced from each other.

17. The tube of claim 12 wherein one of the twists is a left handed twist and the other twist is a right handed twist.

18. The tube of claim 12 wherein one of the twists is a left handed twist and the other twist is a left handed twist.

19. The tube of claim 1 wherein one of the twists is a right handed twist and the other twist is a right handed twist.

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