United States Patent [19]

Pasternak

[11] **3,780,799**

[45] **Dec. 25, 1973**

[54] **HEAT EXCHANGERS AND METHOD OF MAKING SAME**

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[22] Filed: **June 26, 1972**

[21] Appl. No.: **266,501**

Related U.S. Application Data

[63] Continuation of Ser. No. 85,958, Nov. 2, 1970.

[52] **U.S. Cl.** ..... **165/150**, 29/157.3 B, 165/151

[51] **Int. Cl.** **F28f 1/30**

[58] **Field of Search** ..... 165/150, 151; 29/157.3 B

[56] **References Cited**

UNITED STATES PATENTS

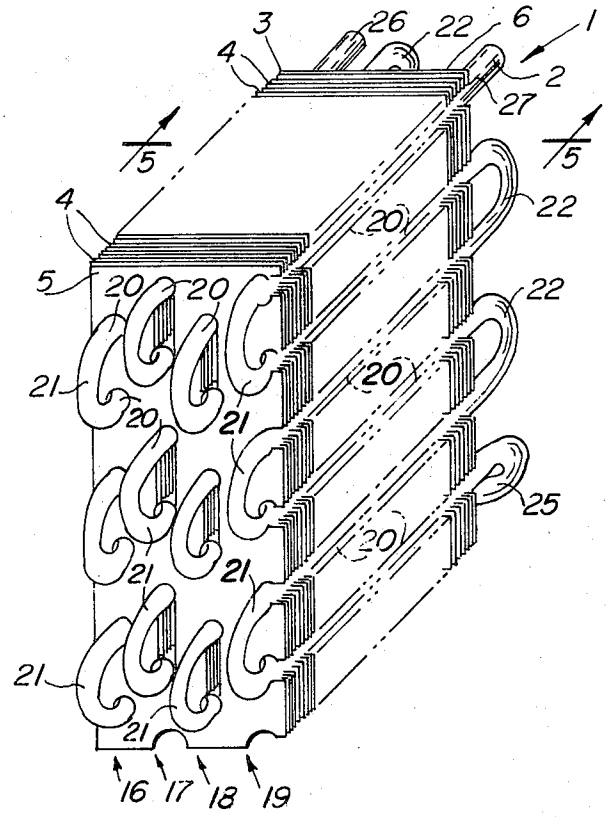
1,773,249	8/1930	Yeager	165/150 X
1,788,068	1/1931	Scott	165/150 X
2,038,912	4/1936	Summers	165/150
2,170,774	8/1939	Fagan	165/150 X
2,181,107	11/1939	Przyborowski	165/150 X
2,462,511	2/1949	Kramer	165/150 X
3,433,300	3/1969	Pasternak	165/151
2,747,258	5/1956	Kramer	29/157.3 B

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[57] **ABSTRACT**

Heat exchangers of the combination plate-fin and side-entry cross-fin type embodying a one-piece cross-fin and a serpentine, one-piece tubular member with return bends disposed at opposite sides of the fins, and method of making the same.

19 Claims, 8 Drawing Figures



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SHEET 1 OF 2

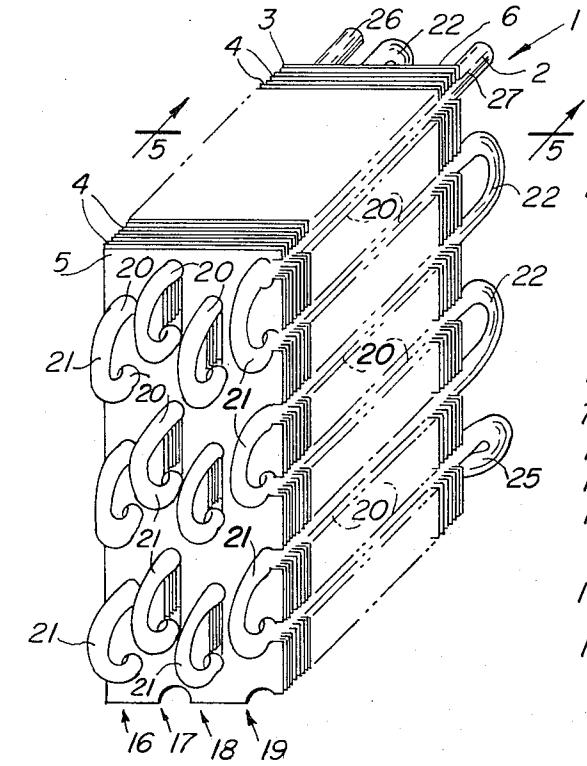


FIG - 1

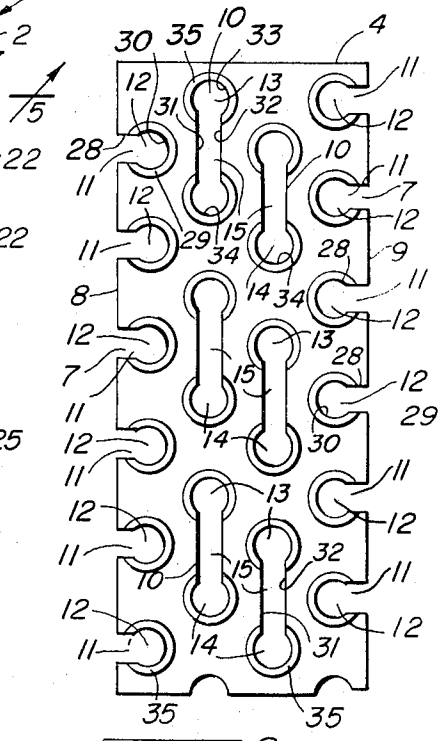


FIG - 2

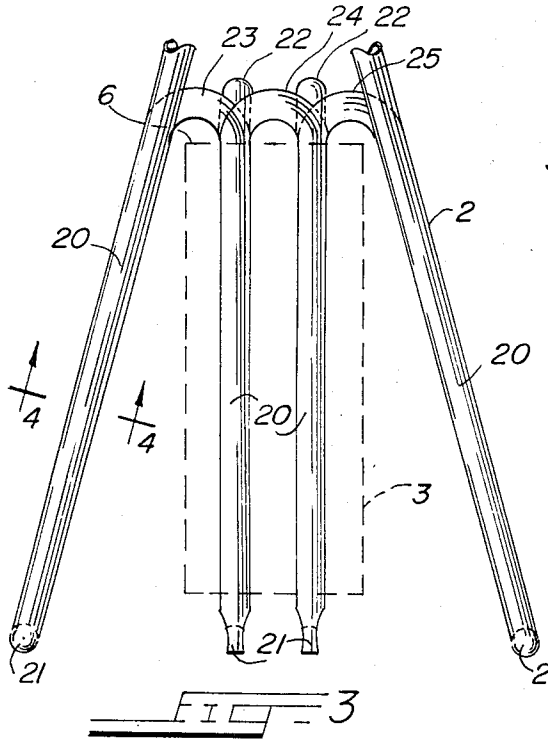


FIG - 3

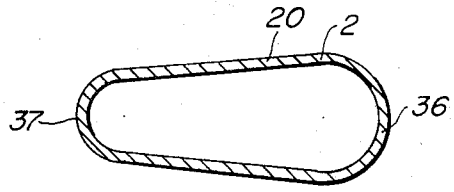


FIG - 4

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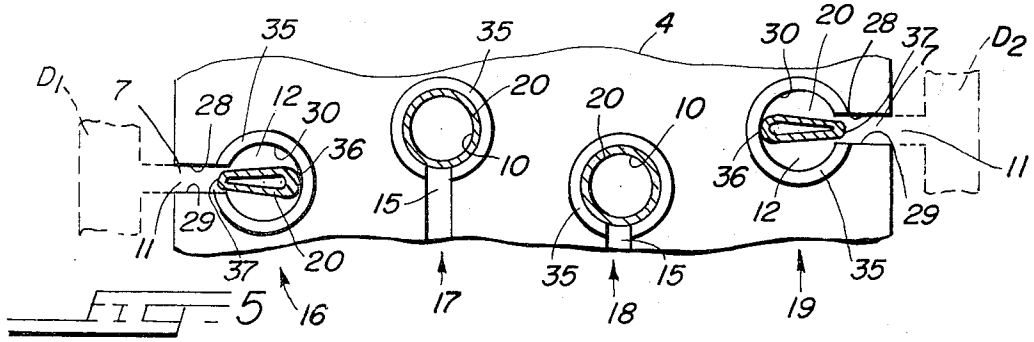


FIG. 5

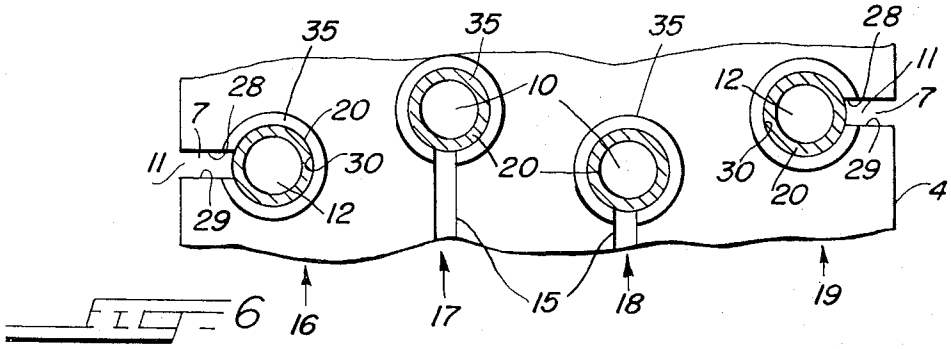


FIG. 6

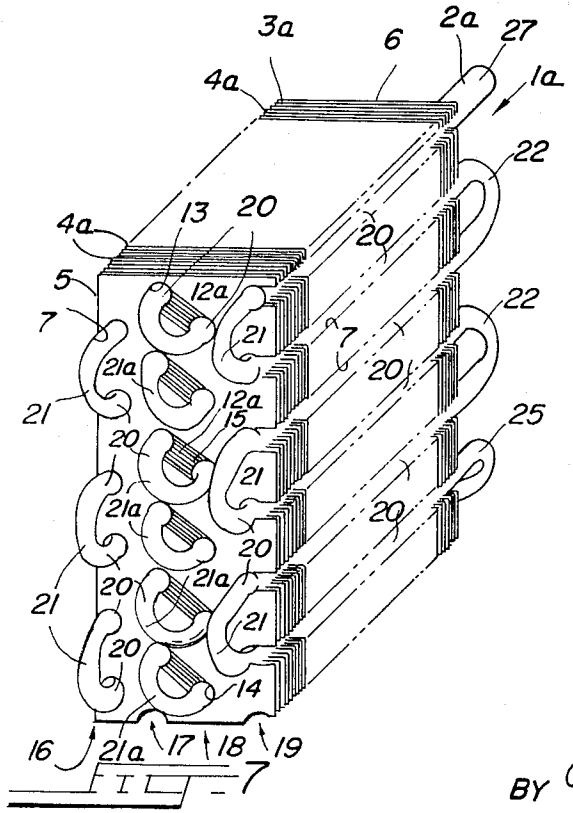


FIG. 7

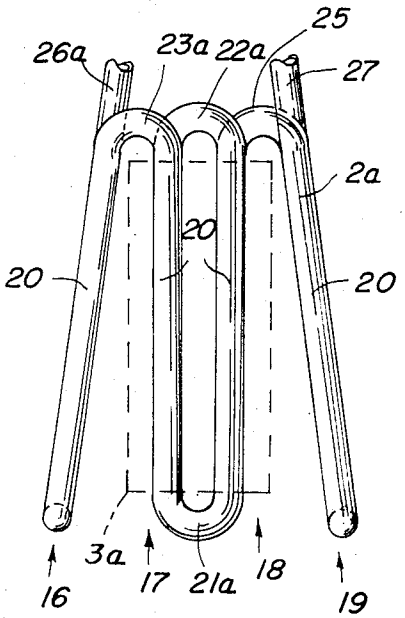


FIG. 8

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HEAT EXCHANGERS AND METHOD OF MAKING SAME

This is a continuation of application Ser. No. 85,958, filed Nov. 2, 1970.

BACKGROUND OF THE INVENTION

This invention relates to heat exchangers and, more particularly, to heat exchangers of the cross-fin type, and the method of making the same.

It is a primary object of the present invention to afford a novel cross-fin type of heat exchanger, and a novel method of making the same.

Another object is to afford a novel heat exchanger embodying a novel combination plate-fin and side-entry cross-fin construction.

A further object of the present invention is to afford a novel method of making a cross-fin type of heat exchanger.

Heretofore, the cross-fin type of heat exchangers commonly used in the refrigeration and air-conditioning fields have been of two types, namely, the plate-fin type and the side-entry type. In the plate-fin type of heat exchangers, the tubing forming the coil portion of the heat exchangers has been inserted longitudinally through openings formed in the cross-fins of the heat exchanger in inwardly spaced relation to the marginal edges thereof. The tubing in such heat exchangers is normally disposed in a serpentine pattern with substantially straight parallel passes of the tubing interconnected at their ends by return bends. Commonly, the return bends of such heat exchangers have been soldered to the ends of the respective passes interconnected thereby after the passes have been inserted through the fins. In this latter type of heat exchanger, the openings in which the passes of the tubing are mounted may have a continuous side wall, so that the tubing mounted therein may be connected to, or engaged with the fin along the entire outer periphery of the tubing.

Another type of plate-fin heat exchangers heretofore known in the art is of the type wherein the fins have elongated openings therethrough, with the return bends and the connected pairs of passes being inserted, as a unit, through respective ones of the openings. In such heat exchangers, the fins do not contact the passes throughout the periphery thereof, the end portions of each opening in which a respective pair of passes is mounted being interconnected by a central portion of the opening, and thus reducing the contact of the cross fins with the outer periphery of the tubing. In an effort to reduce this lost contact between the cross-fins and the passes mounted therein to a minimum, efforts have been heretofore made in the art to reduce the width of the central portions of such elongated openings by affording openings, commonly referred to in the art as being of the "dog-bone" type, wherein the central portions thereof are of lesser widths than the diameters or widths of the end portions. This has required that the return bends be of reduced width for insertion through such openings, and that the return bends in the finished product either be of reduced cross-section or that they be expanded after insertion through the openings, as disclosed in U.S. letters Pat. No. 2,747,258, issued to I. Kramer.

In the aforementioned side-entry type of heat exchangers, the cross-fins thereof have slots formed in the marginal edge portions thereof and the tubing is inserted transversely into the slots. With such construction, of course, tubing inserted into the slots cannot have contact with the cross-fins throughout the entire outer periphery of the tubing, the peripheral contact being reduced at least by the width of the portion of the slot through which the tubing is inserted into the fins. Heretofore, it has been common practice in the manufacture of side-entry type heat exchangers to form the aforementioned slots with an entry portion leading into a body portion, and with the entry portion smaller in width than the body portion, so that the tubing may be inserted transversely through the entry portion into the body portion, and then expanded. Such expansion of the tubing serves two purposes, namely, to interlock the cross-fins and tubing against removal from each other, and to engage the tubing with the side walls of the body portions.

Of course, in a side-entry heat exchanger, such contact between the cross-fins and the entire outer periphery of the tubing is impossible. In this latter type of heat exchanger, the tubing is moved transversely through the open ends of outwardly opening slots formed in the marginal edge portions of the cross-fins into the closed ends thereof. With such construction, the peripheral contact of the tubing with the cross-fins can never be greater than the periphery of the tubing minus the width of the entry opening of the slots. Prior to my invention, as disclosed in the U.S. letters Pat. No. 3,433,300, and my co-pending application for U.S. letters Pat., Ser. No. 770,338, filed Oct. 24, 1968, now U.S. Pat. No. 3,546,763, the width of the entry portion of the slots commonly was a substantial portion of the periphery, so that there was a substantial disparity between the heat transfer afforded by plate-fins and side-entry fins previously known in the art.

Prior to my aforementioned earlier invention, in the manufacture of side-entry type heat exchangers, it had been a common practice to use tubing having such a normal outside diameter that it could be inserted transversely through the entry portion of the slots in the marginal edge portions of the cross-fins into the body portions thereof and then to expand the tubing, transversely to the longitudinal center line of the entry portion, into the enlarged body portions of the slots by the application of external pressure, as disclosed in U.S. letters Pat. Nos. 2,540,339 and 2,567,716 issued to R. W. Kritzer; or to first flatten the passes of the tubing, having a normal outside diameter greater than the width of the entry portion of the slots, so that the tubing could be inserted transversely through the entry portions into the body portions of the slots and, then, by the application of external pressure expand the tubing into the body portions of the slots as disclosed in U.S. letters Pat. No. 2,913,806, issued to R. W. Kritzer.

Although these methods of fabricating side-entry type heat exchangers have been highly successful and have had much commercial success, they had certain inherent disadvantages, such as, for example, requiring the width of the entry portion of the slots to be a substantial portion of the ultimate length of contact between the tubes and the side wall of the body portions of the slots in which the tubes were mounted; requiring substantial external force to be applied to the tubing in order to expand it into the body portion; or requiring substantial internal pressure, of sufficient magnitude that it tended to blow out or rupture the return bends

of the tubing prior to effecting proper expansion of the tubing in the body portions of the slots.

My aforementioned prior invention, as disclosed in U.S. Pat. No. 3,433,300, and the application, Ser. No. 770,338, enabled side-entry cross-fin type of heat exchangers to be afforded wherein the width of the entry portions of the slots in the fins was very small as compared to the widths or diameters of the body portions thereof, and the tubing could be flattened to a thickness which was little greater than the thickness of the tube if it were completely flattened, when it was being inserted into the slots, and, thereafter, by a combination of external pressure and internal pressure, the tubing could then be effectively expanded itno the body portions of the slots.

It is an important object of the present invention to afford improvements over all of the aforementioned type of heat exchangers heretofore known in the art, and to afford improvements over all of the aforementioned methods of making heat exchangers heretofore known in the art.

Another object of the present invention is to afford a novel heat exchanger of the cross-fin type embodying a one-piece coil, with the tubing forming the coil portion of the heat exchanger being disposed both in openings and in slots of the aforementioned plate-fin and side-entry fin type, respectively. It is to be understood that the term "one-piece," as used with respect to the coil portion of the heat exchangers referred to herein is to be construed as meaning a coil, including the passes and return bends thereof, which is made of a single, unitary piece of tubing as distinguished from a coil which is made up of two or more pieces of tubing which have been joined together.

Yet another object of the present invention is to afford a novel heat exchanger of the aforementioned type embodying cross-fins having plate-fin type openings therethrough and side-entry fin type slots therein, with a serpentine, one-piece coil disposed in said openings and slots in a novel and expeditious manner.

A further object is to afford a novel heat exchanger of the combination plate-fin and side-entry fin type, and embodying a serpentine, one-piece coil, wherein the coil thereof is disposed in good, extensive heat-transfer contact with the cross-fins.

Another object of the present invention is to afford a novel heat exchanger of the combination plate-fin and side-entry fin type, wherein it is unnecessary to secure the cross-fins thereof to the coils thereof by soldering, or the like, in order to afford good heat transfer between the fins and the coils, or in order to firmly hold the fins on the coils.

Yet another object of the present invention is to provide a novel combination plate-fin and side-entry fin type heat exchanger which is practical and efficient in operation, and which may be readily and economically produced commercially.

A further object of the present invention is to afford a novel method of making a combination plate-fin and side-entry fin type of heat exchanger, which method is practical and efficient and may be readily used commercially.

Other and further objects of the present invention will be apparent from the following description and claims and are illustrated in the accompanying drawings, which, by way of illustration, show preferred embodiments of the present invention and the principles thereof and what I now consider to be the best mode in which I have contemplated applying these principles. Other embodiments of the invention embodying the same or equivalent principles may be used and structural changes may be made as desired by those skilled in the art without departing from the present invention and the purview of the appended claims.

DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. **1** is a perspective view of a heat exchanger embodying the principles of the present invention;

FIG. **2** is a side elevational view of a cross-fin of the type embodied in the heat exchanger shown in FIG. **1**;

FIG. **3** is a top plan view of the coil embodied in the heat exchanger shown in FIG. **1**, showing the coil in a preferred operative position prior to insertion in the cross-fins of the heat exchanger;

FIG. **4** is an enlarged, detail sectional view taken substantially along the line **4—4** in FIG. **3**;

FIG. **5** is a fragmentary, detail sectional view taken substantially along the line **5—5** in FIG. **1**, and showing the coil of the heat exchanger in an intermediate step in the construction of the heat exchanger;

FIG. **6** is a fragmentary, detail sectional view, similar to FIG. **5**, but showing the coil of the heat exchanger in completed form;

FIG. **7** is a perspective view similar to FIG. **1**, showing a modified form of the heat exchanger; and

FIG. **8** is a top plan view, similar to FIG. **3**, but showing the coil of the heat exchanger shown in FIG. **7**.

DESCRIPTION OF THE EMBODIMENTS SHOWN HEREIN

A heat exchanger **1**, embodying the principles of the present invention, is shown in FIGS. **1–6** of the drawings to illustrate the presently preferred embodiment of the present invention.

The heat exchanger **1** embodies, in general, a one-piece tubular coil **2** having a fin assembly **3**, consisting of a plurality of closely spaced cross-fins **4**, mounted thereon, FIG. **1**. If desired, the opposite ends **5** and **6** of the fin assembly **3** may consist of header plates.

The cross-fins **4** are of a combination plate-fin and side-entry type, as illustrated in FIG. **2**. Each fin **4** is rectangular in shape and embodies a plurality of identical side-entry slots **7** disposed in spaced relation to each other in the respective longitudinal marginal edge portions **8** and **9** of the fin **4**, and a plurality of openings **10** disposed in spaced relation to each other and to the marginal edges of the fin **4**.

Each of the slots **7** has an entry portion **11** which extends inwardly from a respective longitudinal marginal edge **8** or **9** of the respective fins **4**, and an enlarged body portion **12** in communication with the inner end of the entry portion **11** and extending inwardly therefrom. The slots **7** are preferably so disposed in each of the fins **4** that the entry portions **11** in each of the longitudinal edge portions **8** and **9** are disposed in parallel relation to each other, with the longitudinal center lines of the entry portions **11** in each edge portion **8** and **9** being disposed midway between the longitudinal center lines of adjacent pairs of the entry portions **11** in the other edge portion **9** or **8**.

Each of the openings **10** is elongated in shape, embodying oppositely disposed end portions **13** and **14** interconnected by a central portion **15**. Preferably, the

openings 10 are of the aforementioned type known in the art as the "dog-bone" type, the end portions 13 and 14 thereof being of equal size, and the central portions 15 thereof being of substantially lesser width than the widths or diameters of the end portions 13 and 14.

In the preferred form of heat exchanger 1 shown in FIGS. 1–6, the openings 10 are disposed in such position in the cross-fins 4 that the longitudinal center lines thereof are disposed in parallel relation to the marginal edges 8 and 9 of the fins 4. Also, preferably, in a heat exchanger such as that of the type shown in FIGS. 1–6, the openings 10 are so disposed in the fins 4 that the end portions 13 and 14 therein are disposed horizontally opposite central portions 15 of adjacent openings 10, as viewed in FIG. 2, and the horizontally extending center lines through the end portions 13 and 14, as viewed in FIG. 2, are disposed between the body portions 12 of respective pairs of the slots 7 disposed adjacent to the respective openings 10, FIG. 2. With such construction, and with the openings 10 and the slots 7 so disposed in the fins 4, good heat transfer paths through the fins 4 are assured.

The coil 2 may be formed of any suitable material, such as, for example, aluminum, and preferably consists of a single, unitary, one-piece tubular member. It is formed into a serpentine pattern, and in the heat exchanger 1, shown in FIG. 1, it embodies four rows 16, 17, 18 and 19 of elongated, substantially straight passes 20, with adjacent pairs of passes 20 in each of the respective rows 16–19 being interconnected at one end by return bends 21 and at the other end by return bends 22, FIGS. 1 and 3, with the return bends 21 and 22 disposed in uniplanar relation to the respective one of the rows 16–19 of passes 20 in which they are disposed. The lowermost passes 20 in the rows 16 and 18 at the ends thereof in which the return bends 22 are disposed, are interconnected at their ends by return bends 23, and 25, FIG. 3, to the lowermost passes 20 in the rows 17, 18 and 19, respectively and the uppermost passes 20 in the rows 17 and 18 at the ends thereof in which the return bends 21 are disposed, are interconnected to each other by a return bend 24. The upper one of the passes 20 in each of the rows 16 and 19 extends outwardly beyond the fin assembly 3 at the end thereof from which the return bends 22 project to afford an inlet 26 and an outlet 27, respectively, for the coil 2.

With this construction, working fluid, such as, for example, refrigerant may be fed from a suitable source of supply, such as a compressor, not shown, into the coil 2 through the inlet 26 from which it may flow horizontally back and forth through the fin assembly 3, as viewed in FIG. 1, downwardly from one pass 20 to the other in the row 16, across the return bend 23, FIG. 3, to the lower pass 20 in the row 17, horizontally back and forth across the fin assembly 3 upwardly through the passes 20 in the row 17, across the return bend 24 to the upper pass 20 in the row 18, horizontally back and forth across the fin assembly 3 downwardly from one pass 20 to the other in the row 18, across the return bend 25 to the lower pass 20 in the row 19, and then horizontally back and forth across the fin assembly 3 upwardly through the passes 20 in the row 19 and outwardly through the outlet 27.

In the preferred form of the invention shown in the drawings, the shape of the body portions 12 of the slots 7 is that of an arc of a circle, and the entry portions 11, extending outwardly therefrom, are substantially straight, having parallel side walls 28 and 29 extending outwardly from the side walls 30 of the respective body portions 12, FIG. 2.

Preferably, the radius of the arc of the body portion 12 of each of the slots 7 is the same as the normal outside radius of the tubular member affording the coil 2, and the width of each entry portion 11 of the slots 7 is substantially less than the diameter of the body portion 12 to which it is connected, such as, for example, not substantially more than 20 percent of the diameter of the body portion 12.

In the preferred form of the invention shown in the drawings, the shape of the body portions 13 and 14 of the openings 10 is that of an arc of a circle, and the central portions 15, extending therebetween, are substantially straight having parallel side walls 31 and 32 extending between the side walls 33 and 34 of the respective body portions 13 and 14.

Preferably, the radii of the arcs of the body portions 33 and 34 of each of the openings 10 are of such size that when the passes 20 are inserted thereinto, during the assembling of the heat exchanger 1, they pass thereinto with a snug, but relatively freely slidable fit. Also, preferably, the width of each of the central portions 12 of the slots 10 is substantially less than the diameter of the body portions 13 and 14 to which tey are connected, such as, for example, not substantially more than fifty percent of the diameter of the connected body portions 13 and 14.

Flanges or collars 35 are formed on each of the fins 4 around the body portions 12 and the body portions 13 and 14 of the slots 7 and the openings 10, respectively, FIG. 2, to afford reinforcing members for the body portions 12, 13 and 14. The flanges 35 project outwardly from the planes of the body portions of each of the respective fins 4 to afford spacers between adjacent fins 4. Preferably, in the assembled heat exchanger 1, the body portions of the adjacent fins 4 are spaced from each other along the passes 20 of the coil 2 the thickness of the respective flanges 35.

In making the novel heat exchanger 1 in accordance with the principles of the preferred method of the present invention, the cross-fins 4 are formed with the entry portions 11 of the slot 7, and the central portions 15 of the openings 10 substantially narrower than the normal outside diameter of the tube 2. The tube 2 is preformed into the serpentine shape shown in FIG. 3, with the intermediate rows 17 and 18 of the passes 20 disposed in substantially parallel relation to each other, and with the outer rows 16 and 19 of the passes 20 projecting outwardly from the rows 17 and 18 at acute angles thereto. In the preformed tube 2 shown in FIG. 3, the passes 20 in the outer rows 16 and 19, between the return bends 21 and 22 at the opposite ends thereof, are flattened to such a thickness that they may be inserted transversely through the entry portions 11 of the slots 7 into the body portions 12 thereof, during assembly of the coil 2 with the fin assembly 3. Also, in the form of the tube 2 shown in FIG. 3, the return bends 21 in the rows 17 and 18 are flattened to such a thickness that they may be inserted transversely through the central portions 15 of the openings 10, during the assembling of the coil 2 with the fin assembly 3.

With the cross-fins 4 thus constructed, and with the tube 2 thus constituted and arranged, a plurality of the fins 4 may be disposed in stacked relation to each other to afford the substantially rectangular shaped fin as-

sembly 3, FIGS. 1 and 3. The fin assembly 3 may, or may not embody header plates at the end portions 5 and 6 thereof, depending upon the choice of the type of construction to be used, without departing from the principles of the present invention, such header plates, if used, having openings and slots therein corresponding to the openings 10 and the slots 7 in the fins 4.

With the fin assembly 3 thus assembled, the return bends 21 and the respective interconnected pairs of passes 20 in the rows 17 and 18 may be inserted through the corresponding openings 10, with the flattened return bends 21 passing through the central portions 15 of the openings 10, and with the passes 20 passing longitudinally through respective ones of the end portions 13 and 14 in the openings 10. During such insertion of the rows 17 and 18 of the passes 20 into the fin assembly 3, the latter preferably is held in properly stacked position in a suitable jig or fixture, not shown. Preferably, the fin assembly 3 is of such size, and the rows 17 and 18 of passes 20 are inserted thereinto to such position that the passes 20 project outwardly from the opposite ends 5 and 6 of the fin assembly 3, as illustrated diagrammatically in FIG. 3.

With the coil 2 thus disposed in the fin assembly 3, the outer rows 16 and 19 of the passes 20 may be swung laterally inwardly on the return bends 23 and 25, respectively, into position to cause the flattened passes 20 in the two rows 16 and 19 to pass transversely through the entry portions 11 of the slots 7 into the body portions 12 thereof, into the position shown in FIG. 5.

In this position of the passes 20 in the two outer rows 16 and 19, the edge portions 36 thereof, FIGS. 4 and 5, herein referred to as the "leading edge portions," are disposed in abutting engagement with the portions of the side walls 30 of the respective body portions 12, which are disposed on the side of the respective entry portions 11 remote from the respective marginal edges 8 and 9 of the fins 4. Also, in such position of the passes 20 in the outer rows 16 and 19, the edge portions 37 thereof, herein referred to as the "trailing edge portions," project outwardly into the entry portions 11 of the respective slots 7. In addition, in such position of the coil 2, the outer surfaces of the passes 20 in the intermediate rows 17 and 18 are preferably disposed in snug fitting engagement with the side walls 33 and 34 of the respective end portions 13 and 14 in which they are disposed in the openings 10.

With the coil 2 thus disposed in the slots 7 and the openings 10 in the fins 4, it may be subjected to internal pressure sufficient to expand the return bends 21 in the internal rows 17 and 18 from a flattened shape, such as shown in FIG. 3, to a substantially round shape, such as shown in FIG. 1, wherein they are substantially of the same size and shape as that of the original tubing 2; and simultaneously therewith, the passes 20 in the outer rows 16 and 19 may be simultaneously subjected to both the aforementioned internal pressure and an external pressure sufficient to expand them from a flattened shape, such as shown in FIGS. 4 and 5, to a substantially round shape, such as shown in FIG. 6, wherein they completely fill the body portions 12 of the respective slots 7. To accomplish this, the ends 26 and 27 of the coil 2 may be connected to a suitable source of pressurized working fluid, not shown, such as, for example, a suitable source of hydraulic fluid; and the heat exchanger 1 may be mounted in a suitable press, or the like, wherein dies, such as the dies D1 and D2, FIG. 5, may be abuttingly engaged with the trailing edge portions 37 of the passes 20 in the outer rows 16 and 19, respectively, in position to exert the aforementioned external force on the passes 11 at the opposite sides of the fins 4.

As the aforementioned internal and external pressure is applied to the passes 20 in the outer rows 16 and 19, these passes 20 are caused thereby to expand from the flattened shape, shown in FIGS. 4 and 5 to the fully expanded shape shown in FIG. 6. During this time, the dies D1 and D2 preferably continuously move inwardly toward each other in such a manner as to continually clamp the coil 2 therebetween with sufficient force to maintain the leading edge portions 36 of the passes 20 in engagement with the portions of the side walls 30 of the respective body portions 12 disposed directly opposite the respective entry portions 11 of the slots 7. The application of the aforementioned external force serves three main functions, as discussed in greater detail in my aforementioned U.S. Pat. No. 3,433,300 and my application for U.S. letters Pat., Ser. No. 770,338.

The first of these functions is to hold the leading edge portions 36 of the passes 20 in the outer rows 16 and 19 in engagement with the adjacent portions of the side walls 30 of the respective body portions 20, to prevent these portions 36 of the passes 20 from pulling away from the side walls 30 as the coil 2 is expanded, and thus assist in insuring that when expansion of these passes 20 is completed, they will be in firm engagement with the side walls 30 throughout the length of the latter.

The second function of the aforementioned external forces is that the external force thus applied to the trailing edge portions 37, itself, tends to expand the passes 20 to which it is applied, and thereby assist the expansion efforts of the internal pressure applied to these passes 20 of the coil 2.

The third function of the aforementioned external forces applied to the outer passes 20 is to move the trailing edge portions 37 thereof inwardly through the respective entry portions 11 at a rate whereby during expansion of these passes 20 in the body portions 30, the side walls of the expanding passes 20 are maintained out of engagement with the side walls 28 and 29 of the entry portions 11, and out of engagement with the junction of the side wall 28 and 29 with the side walls 30 of the respective body portions 12, to thereby prevent the passes 20 from applying undesirable expanding and tearing forces to the side walls of the slots 7, and also, to assist in insuring a substantially round cross-section for the fully expanded passes.

With this method of manufacturing heat exchangers, such as the heat exchanger 1, it has been found that tubular members, wherein return bends, corresponding to the return bends 21, had been flattened to a thickness of not substantially more than fifty percent of their original diameter, and wherein passes, corresponding to the passes 20 in the outer rows 16 and 19, had been flattened to a thickness of not substantially more than 20 percent of their original diameter, may be expanded to their normal round position in the fin assembly 3 by the use of a combination of internal pressure which is substantially below the pressure necessary to rupture any portion of the coil 2, and an external clamping force which is substantially below the force necessary to buckle or permanently deform fins, such as the fins

4, even when the latter are made from relatively thin and structurally weak material, such as, for example, aluminum having a thickness of 0.006 inches.

Also, it has been found that with this method of manufacture, the flattened outer passes **20** may be expanded into substantially round shape wherein they have again assumed their original outside diameter, or slightly more, so as to firmly engage the side walls **30** of the body portions **12** throughout the length of the side walls **30**, with sufficient force that these passes **20** may be so firmly engaged with the respective side walls **30** that the fins **4** are securely held in position on the coil **2** by this engagement, alone, and that it is unnecessary to afford an additional securing of the cross-fins **4** to the coil **2**, such as, for example, by solder.

It will be observed that the heat exchanger **1**, shown in FIGS. **1–6**, is a four-row heat exchanger embodying two intermediate rows **17** and **18** and two outer rows **16** and **19**. However, as will be appreciated by those skilled in the art, this is merely by way of illustration and not by way of limitation, and a heat exchanger embodying a greater or lesser number of rows may be afforded without departing from the principles of the present invention. Thus, for example, a three-row heat exchanger, embodying the same principles, may be afforded by eliminating one of the rows **17** or **18** and the return bend **24**, transferring either the return bend **23** or **25** from the bottom of the fin assembly **3** to the top thereof, and connecting the remaining intermediate row **17** or **18** to either the outer row **16** or the outer row **19** by the thus transferred return bend **23** or **25**, respectively; or by eliminating either of the outer rows **16** or **19** and transforming the corresponding return bend **23** or **25**, respectively, into either the inlet portion **26** or the outlet **27** of the coil **2**. Also, any number of intermediate rows, similar to the rows **17** and **18**, my be added to the heat exchanger **1** by merely adding such a row and a corresponding return bend, such as the return bend **24**, connected to an adjacent internal row, the return bends **23** and **25** being connected between the outermost ones of the internal rows and the adjacent outer row **16** and **19**, respectively.

A modified form of the present invention is illustrated in FIGS. **7** and **8**. This modified form of the invention embodies the same general principles as the preferred form illustrated in FIGS. **1–6**, inclusive, and parts which are the same as parts shown in FIGS. **1–6** are indicated by the same reference numerals, and parts which are similar but which have been substituted for parts shown in FIGS. **1–6** are indicated by the same reference numerls with the suffix "a" added.

In the heat exchanger **1***a* shown in FIG. **7**, four rows **16**, **17**, **18** and **19** of passes **20** are disposed in a fin assembly **3***a* in the same relative position as the passes **20** are disposed in the fin assembly **3** in the heat exchanger **1** shown in FIG. **1**. The passes **20** in the rows **16** and **19** are interconnected by return bends **21** and **22**, at their respective opposite ends, which, like the corresponding passes in the heat exchanger **1** are disposed in uniplanar relation to the respective rows **16** and **19**.

However, the passes **20** in the intermediate rows **17** and **18**, shown in FIG. **7**, are connected at their respective opposite ends by return bends **21***a* and **22***a*, FIGS. **7** and **8**, which extend between adjacent passes **20** in the two rows **17** and **18**, transversely to the planes of the rows, eliminating the return bend **24** of the heat exchanger **1**.

In addition, in the heat exchanger **1***a*, the openings **12***a* are formed in the cross-fins **4***a* at a transverse angle to the length thereof corresponding to the angle of the return bends **21***a* and **22***a*. As shown in FIG. **7**, the angle of the openings **12***a* and the return bends **21***a* and **22***a* is an acute angle to the length of the fins **4***a*, the angle opening upwardly and to the left, as viewed in FIG. **7**.

With this construction, the flow of working fluid through all of the tubes **20** in the inner row **17** is in one direction, and the flow of the working fluid through all of the tubes **20** in the row **18** is in the opposite direction, rather than the flow being back and forth in adjacent passes in each of the respective rows **17** and **18**, as in the heat exchanger **1**. With the tube **27** constituting the outlet for the coil **2***a*, the flow of working fluid through the heat exchanger **1***a* is such that the flow through the passes **20** in the row **18** is toward the end **6** of the coil assembly **3***a*, and the flow through the passes **20** in the row **17** is toward the end **5** of the fin assembly **3***a*. This means that the flow through the upper pass **20** in the row **17**, shown in FIG. **7**, is in the reverse direction to the corresponding pass shown in FIG. **1**, and that, therefore, the return bend **23***a* connected between the rows **16** and **17** is connected to the upper passes **20** thereof and the inlet end **26***a* is connected to the end of the lower pass **20** in the row **16**, FIG. **8**.

In assembling the heat exchanger **1***a* the same general procedure is followed as in assembling the heat exchanger **1**. Thus, for example, the fins **4***a* are formed with the slots **7** in the openings **12***a* extending therethrough and are then disposed in stacked relation to each other to afford the fin assembly **3***a*. Also, the coil **2***a* is formed into serpentine form with the intermediate rows **17** and **18** of the passes **20** disposed in substantially parallel, spaced relation to each other, and with the outer rows **16** and **19** of the passes **20** extending outwardly from the rows **17** and **18** at an acute angle thereto, FIG. **8**. In addition, the return bends **21***a* and the passes **20** in the rows **16** and **19** are flattened. However, in the formation of the cross-fins **4***a*, openings **12***a* are formed therein at the aforementioned acute angles, and, in bending the coil **2***a* into the aforementioned serpentine form, the return bends **21***a* and **22***a* are formed at the same acute angles; the return bend **23***a* is formed at the top of the row **16**, rather than at the bottom thereof; and the inlet portion **26***a* is formed on the lower pass **20** in the row **16** rather than on the top pass thereof.

After the fin assembly **3***a* has thus been formed, and the coil **2***a* has been preformed into the aforementioned serpentine form, the return bends **21***a* and the passes **20** in the rows **17** and **18** may be inserted through the openings **12***a* in the fin assembly **3***a* in the same manner as heretofore described with respect to the corresponding portions of the heat exchanger **1**. Thereafter, the outer rows **16** and **19** of the passes **20** may be inserted transversely into the adjacent slots **7**, and these latter passes, and the return bends **21***a* may be expanded in the same manner as heretofore described with respect to the corresponding portions of the heat exchanger **1**.

The heat exchanger **1***a*, like the heat exchanger **1**, is shown in the drawings herein as embodying four rows of passes **20**. However, as with respect to the heat exchanger **1**, this is merely by way of illustration and not

by way of limitation, and as will be appreciated by those skilled in the art, the heat exchanger **1***a* may embody a greater or lesser number of rows of passes **20** without departing from the principles of the present invention. Thus, for example, the heat exchanger **1***a* may be changed to a heat exchanger embodying three rows of passes **20** by eliminating one of the outermost rows **16** and **19** or by eliminating one of the inner rows **17** and **18** in the same manner as heretofore described with respect to the heat exchanger **1**. In addition, any number of intermediate rows, such as the rows **17** and **18**, may be added to the heat exchanger **1***a* in a manner similar to that heretofore described with respect to the heat exchanger **1**. However, in this latter instance, for each such intermediate row added to the heat exchanger **1***a*, a corresponding set of return bends **21***a* and **22***a* would be added thereto, rather than adding a return bend such as the return bend **24**, embodied in the heat exchanger **1**, this latter return bend being eliminated in the heat exchanger **1***a*.

Also, it is to be observed that although the openings **12***a* are shown in FIG. **7** as being disposed at an acute angle to the length of the fins **4***a*, which opens upwardly to the left, as viewed in FIG. **7**, this also is merely by way of illustration and not by way of limitation, and they may be disposed at any other desired acute angle, or in perpendicular relation to the length of the fins **4***a*, if desired, without departing from the purview of the present invention. The primary difference between the heat exchanger **1** shown in FIG. **1** and the heat exchanger **1***a* shown in FIG. **7** is that the return bends **21** and **22** in the heat exchanger **1** are disposed in uniplanar relation to and interconnect adjacent passes in respective ones of the inner rows, such as the rows **17** and **18**, whereas, in the heat exchanger **1***a*, the return bends **21***a* and **22***a* extend transversely to the planes of the inner rows, such as the rows **17** and **18**, and interconnect passes **20** in adjacent rows.

From the foregoing, it will be seen that the present invention affords a novel heat exchanger of a combination plate fin and side-entry fin type.

Also, it will be seen that it affords a heat exchanger wherein the pattern of the placement of the passes and return bends may be readily varied.

Also, it will be seen that the present invention affords a novel combination fin and side-entry type of heat exchanger which is practical and efficient in operation, and which may be readily and economically produced commercially.

Also, it will be seen that the present invention affords a novel and practical method of making heat exchangers, which method is efficient and may be readily utilized commercially.

Thus, while I have illustrated and described the preferred embodiments of my invention, it is to be understood that these are capable of variation and modification, and I therefore do not wish to be limited to the precise details set forth, but desire to avail myself of such changes and alterations as fall within the purview of the following claims.

I claim:

1. A heat exchanger comprising
- a. one-piece cross-fins having
  - 1. slots opening outwardly through the marginal edge portion thereof, and
  - 2. openings, having a closed periphery, disposed in spaced relation to said marginal edge portion, and
- b. a one-piece coil of tubing
  - 1. having a serpentine form, and
  - 2. comprising
    - a'. passes and
    - b'. return bends interconnecting respective pairs of said passes,
- c. certain of said passes being disposed in said slots, and
- d. other of said passes being disposed in said openings.

2. A heat exchanger as defined in claim **1**, and in which
- a. said certain passes are laterally spaced from each other along said marginal edge portion, and
- b. said other passes are laterally spaced from each other in said cross-fins.

3. A heat exchanger as defined in claim **1**, and in which
- a. said other passes are disposed in not less than one row.

4. A heat exchanger as defined in claim **1**, and in which
- a. said other passes are disposed in a plurality of rows, and
- b. said return bends interconnect adjacent ones of said passes, and
- c. said return bends include return bends
  - 1. interconnecting said other passes disposed in respective ones of said rows, and
  - 2. disposed in uniplanar relation to said respective row.

5. A heat exchanger as defined in claim **1**, and in which
- a. said other passes are disposed in a plurality of rows, and
- b. said return bends interconnect adjacent ones of said passes, and
- c. said return bends interconnecting said other passes in said rows
  - 1. extend transversely to the planes of said rows, and
  - 2. interconnect passes in adjacent ones of said rows.

6. A heat exchanger as defined in claim **1**, and in which
- a. said passes disposed in said slots are disposed in two rows of laterally spaced passes,
- b. said rows are disposed on opposite sides of said cross-fins, and
- c. said other passes are disposed in not less than one row of laterally spaced other passes between said two first mentioned rows.

7. A heat exchanger as defined in claim **6**, and in which
- a. said return bends have substantially the same outside diameter as said passes, and
- b. said openings have
  - 1. two end portions having substantially the same inside diameter as the outside diameter of said passes, and
  - 2. a central portion interconnecting said end portions and having a width less than the diameter of said return bends.

8. A heat exchanger as defined in claim 1, and in which
a. said slots embody
1. entry portions opening outwardly through said marginal edge portion, and
2. body portions disposed in inwardly spaced relation to said marginal edge portion,
b. said body portions have substantially the same inside diameters as the outside diameters of said passes, and
c. said entry portions are of lesser width than said diameters of said body portions.

9. A heat exchanger as defined in claim 8, and in which
a. said return bends have substantially the same outside diameter as said passes, and
b. said openings have
1. two end portions having substantially the same inside diameter as the outside diameter of said passes, and
2. a central portion interconnecting said end portions and having a width less than the diameter of said return bends.

10. A heat exchanger as defined in claim 9, and in which
a. said entry portions and said central portions
1. comprise permanently cut-away portions of said fins, and
2. are permanently of said respective widths thereof.

11. The method of making a heat exchanger comprising
a. forming a one piece coil of tubing having
1. an outer elongated pass,
2. two other elongated passes,
3. a return bend connecting said outer pass to one of said other passes, and
4. another return bend interconnecting said other passes,
b. forming a cross-fin assembly having
1. a slot in the marginal edge portion thereof for the side entry of a pass thereinto, and
2. an opening having a closed periphery, disposed in spaced relation to the marginal edge of said assembly,
c. inserting said other return bend and said two passes through said opening in a direction longitudinally of said two passes into position wherein said two passes are disposed in said opening, and
d. moving said outer pass transversely into said slot.

12. The method of making a heat exchanger as defined in claim 11, and
a. in which
1. said opening is formed with
a'. two end portions having an inside diameter not less than the normal outside diameter of said tubing at said other return bend and at said two passes, and
b'. a central portion extending between said end portions and having a width less than said outside diameter, and
b. which includes
1. flattening said other return bend to a thickness less than said width of said central portion,
2. inserting said other return bend and said two passes through said opening in a direction longitudinally of said two passes, with said return bend passing through said central portion and said two passes passing through respective ones of said end portions, into position wherein said two passes are disposed in respective ones of said end portions, and
3. expanding said other return bend to a diameter not substantially less than said normal diameter.

13. The method of making a heat exchanger as defined in claim 11, and
a. in which
1. said slot is formed with
a'. an entry portion opening outwardly through the marginal edge of said assembly, and
b'. a body portion extending from said entry portion on the side thereof remote from said marginal edge, and having a greater width perpendicular to the longitudinal center line of said entry portion than the narrowest width of said entry portion, and
b. which includes
1. flattening said outside pass to a thickness less than the width of said entry portion,
2. inserting said outside pass transversely through said entry portion into said body portion, and
3. expanding said outside pass in said body portion to a diameter not substantially less than said normal diameter.

14. The method of making a heat exchanger comprising
a. forming a cross-fin assembly having
1. slots in the marginal edge portion thereof, and
2. openings disposed in spaced relation to the marginal edge of said assembly,
b. forming tubing into a one piece coil of serpentine form having
1. a plurality of elongated outer passes disposed in laterally spaced relation to each other,
2. return bends interconnecting respective pairs of said outer passes,
3. a plurality of other elongated passes disposed in laterally spaced relation to each other and extending at an acute angle to said outer passes, and
4. other return bends interconnecting adjacent ones of said other passes,
c. inserting said other return bends and said other passes through said openings, in a longitudinal direction relative to said other passes, into position to dispose said other passes in said openings,
d. inserting said outer passes laterally into said slots, and
e. securing said coil to said assembly.

15. The method of making a heat exchanger as defined in claim 14, and
a. in which
1. each of said slots has an entry portion opening outwardly through the marginal edge of said assembly, and
2. a body portion extending from said entry portion on the side thereof remote from said marginal edge, and having a greater width perpendicular to the longitudinal center line of said entry portion than the narrowest width of said entry portion, and
b. which includes

1. flattening said outer passes to a width less than the narrowest width of said entry portions prior to insertion of said outer passes into said slots,
2. inserting said thus flattened outer passes transversely through said entry portions into said body portions in the direction of said flattening, and
3. expanding said outer passes in said body portions into abutting engagement with the side walls of said body portions.

16. The method of making a heat exchanger as defined in claim **15,** and in which

a. said expanding of said outer passes is accomplished by the simultaneous application of
1. external pressure on said outer passes effective to maintain said passes in engagement with the portions of said side walls of said respective body portions in which they are mounted remote from said entry portions from which said body portions extend, and
2. internal pressure applied by working fluid inside said tubing.

17. The method of making a heat exchanger as defined in claim **14,** and

a. in which
1. said openings are formed with
a'. two end portions, and
b'. a central portion extending between said end portions and having a width less than that of said end portions, and

b. which includes
1. flattening said other return bends to a thickness less than said width,
2. inserting said other return bends and the respective two other passes interconnected thereto through said opening in a direction longitudinally of said two passes, with said return bends passing through said central portion and said two passes passing through respective ones of said end portions, into position wherein said two passes are disposed in respective ones of said end portions, and
3. expanding said other return bends.

18. The method of making a heat exchanger as defined in claim **17,** and

a. in which
1. each of said slots has an entry portion opening outwardly through the marginal edge of said assembly, and
2. a body portion extending from said entry portion on the side thereof remote from said marginal edge, and having a greater width perpendicular to the longitudinal center line of said entry portion than the narrowest width of said entry portion, and

b. which includes
1. flattening said outer passes to a width less than the narrowest width of said entry portions prior to insertion of said outer passes into said slots,
2. inserting said thus flattened outer passes transversely through said entry portions into said body portions in the direction of said flattening, and
3. expanding said outer passes in said body portions into abutting engagement with the side walls of said body portions.

19. The method of making a heat exchanger as defined in claim **18,** and

a. in which said expanding of said outer passes is accomplished by the simultaneous application of
1. external pressure on said outer passes effective to maintain said passes in engagement with the portions of said side walls of said respective body portions in which they are mounted remote from said entry portions from which said body portions extend, and
2. internal pressure applied by working fluid inside said tubing, and
3. said return bends are so expanded by internal pressure applied by working fluid inside said tubing, and

b. which includes expanding said other passes into abutting engagement with the side walls of said end portions by internal pressure applied by said working fluid inside said tubing.

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