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(54) **METHOD OF EXPANDING CORRUGATED TUBE AND MANUFACTURING A HEAT EXCHANGER WITH EXPANSION TUBE**

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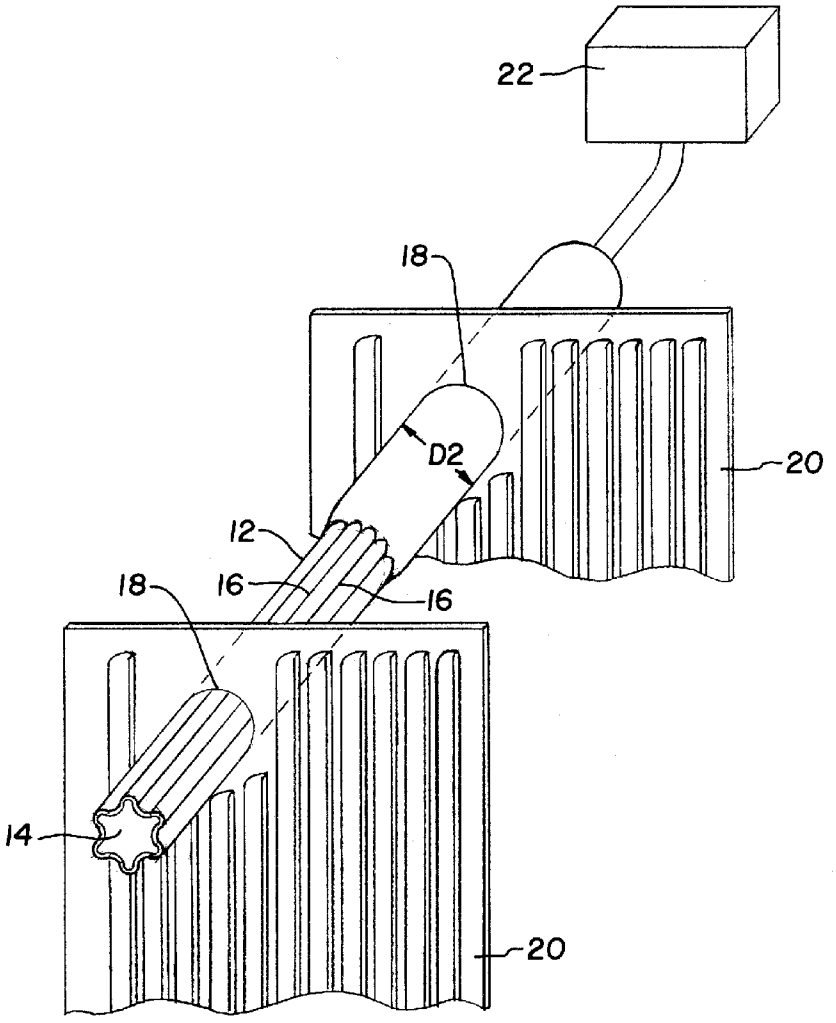
(57) **ABSTRACT**

A method of manufacturing a heat exchanger coil, the method comprising the steps of reconfiguring the cross-sectional shape of an elongate tube from a substantially round cross-sectional shape having a first outer circumference to a reduced or corrugated cross-sectional shape having a second outer circumference which is less than the first outer circumference, forming a plurality of u-shaped hairpin tubes from the elongate tube, the u-shaped hairpin tubes each having a pair of parallel legs, inserting each of the parallel legs of the hairpin tube through a predetermined opening in at least one fin plate, attaching a plurality of return bends to the u-shaped hairpin tubes to form a predetermined circuitry and then incrementally applying fluid pressure from a fluid pressure source to an internal channel of the circuitry to incrementally expand the circuitry to form a tight heat transfer bond between the circuitry and at least one wall of the predetermined opening.



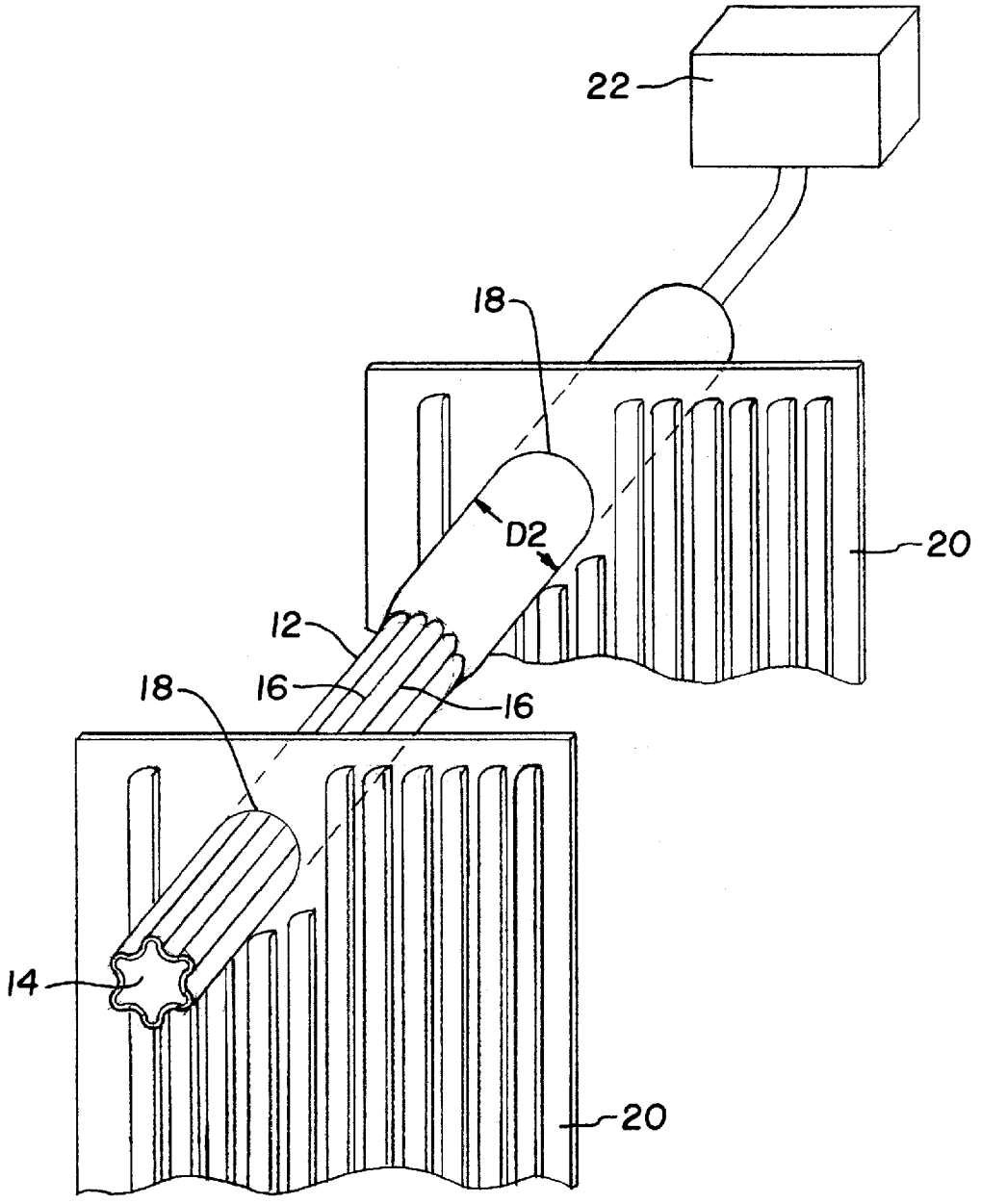


Fig. 1

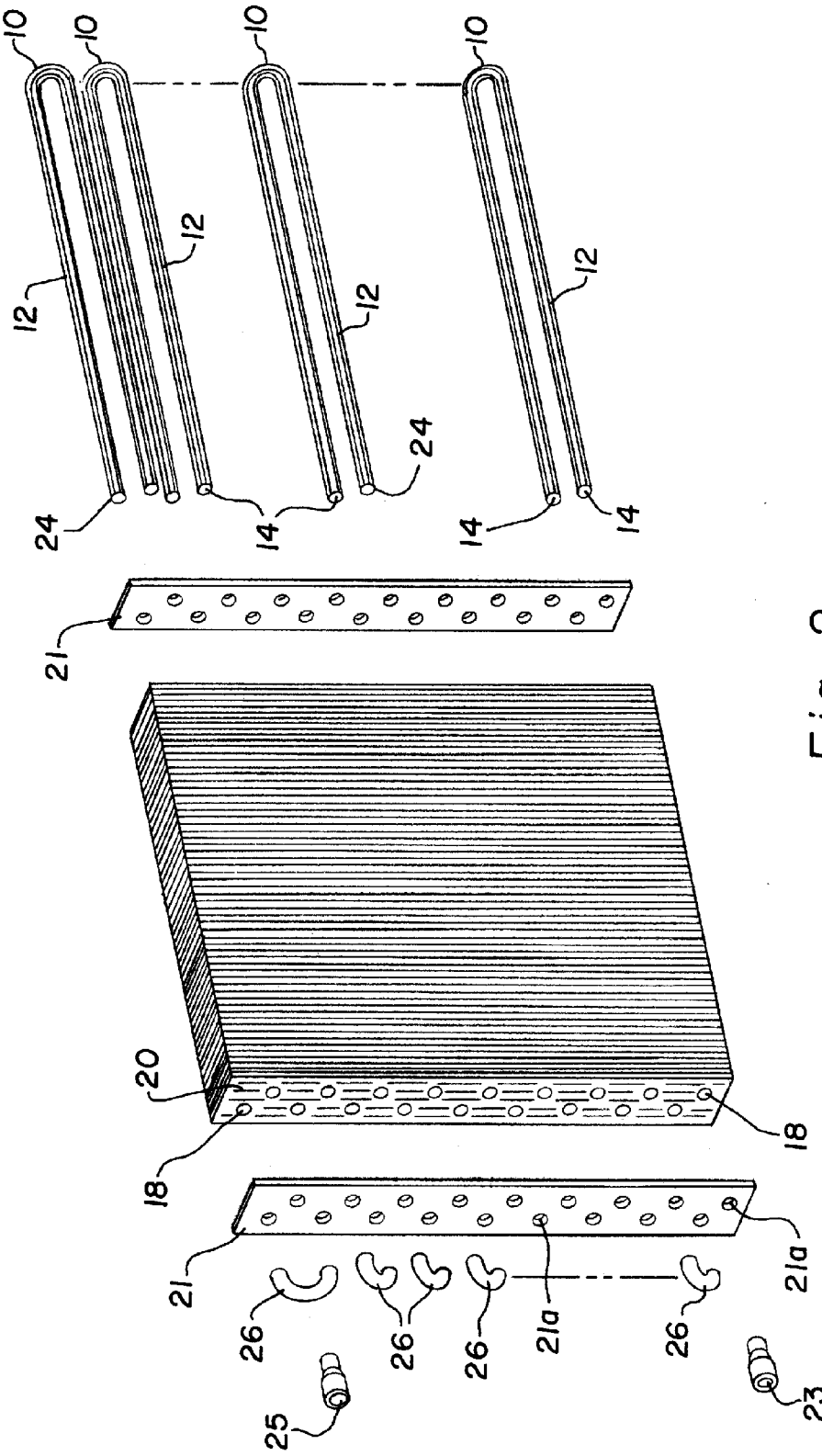

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Fig. 2

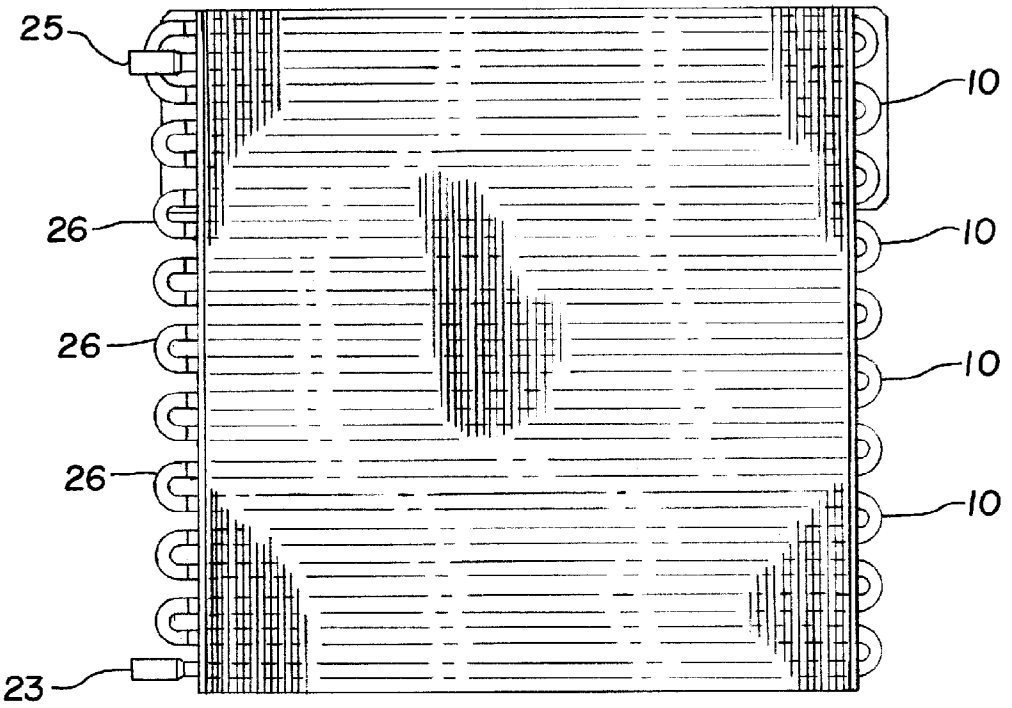

Fig. 3

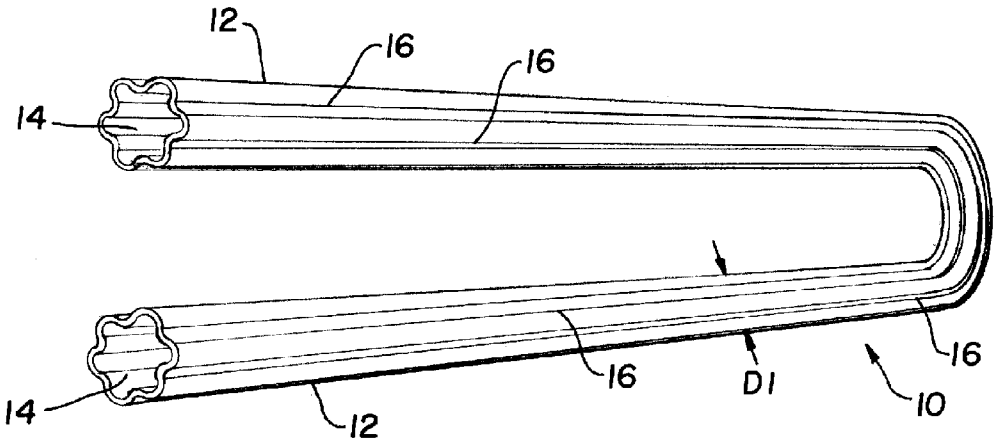

Fig. 4

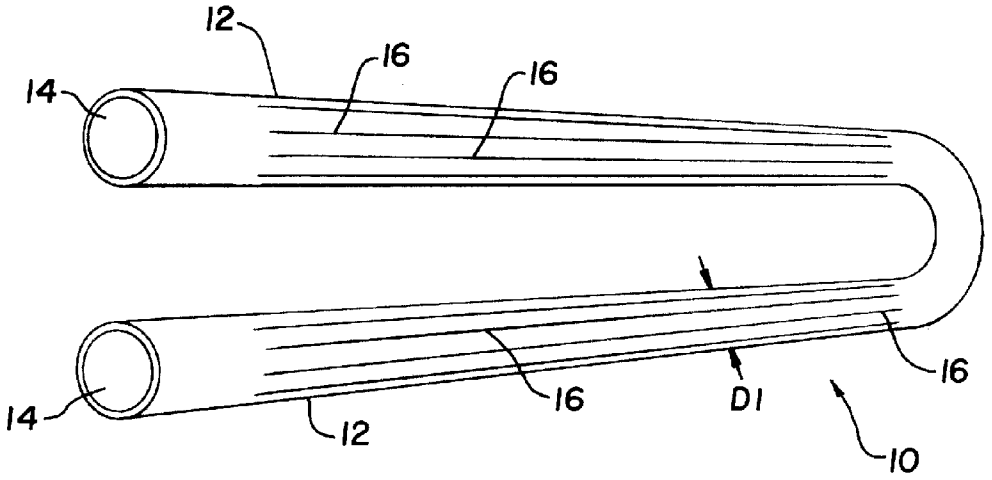

Fig. 4A

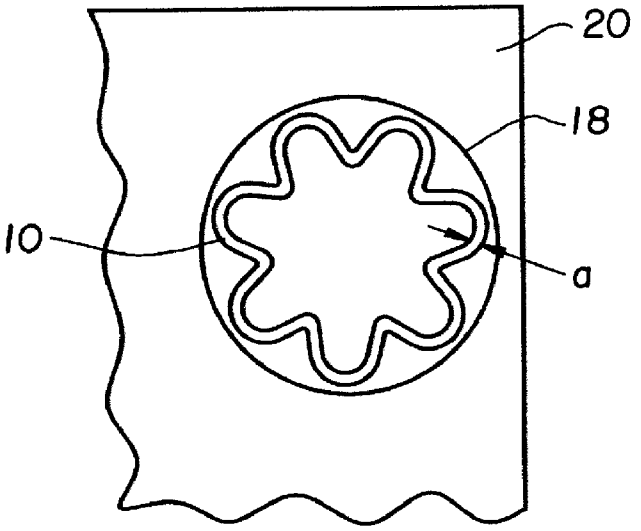

Fig. 5A

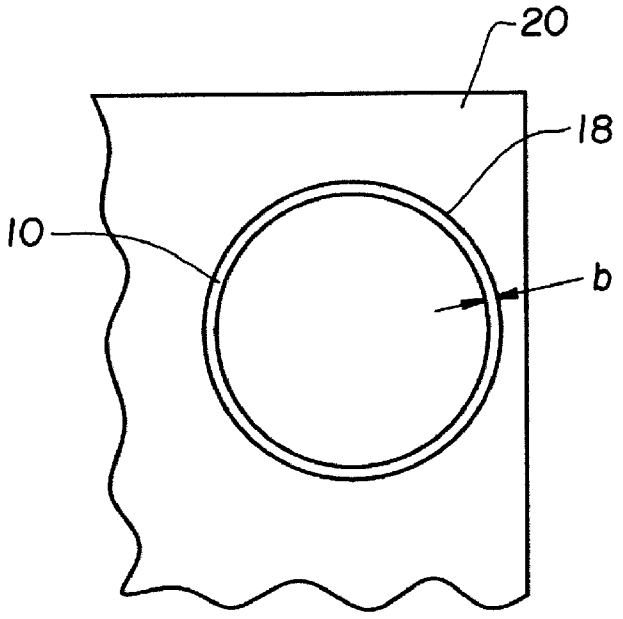

Fig. 5B

METHOD OF EXPANDING CORRUGATED TUBE AND MANUFACTURING A HEAT EXCHANGER WITH EXPANSION TUBE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This is a non-provisional application based upon U.S. Provisional Patent Application Ser. No. 61/372,584, entitled "METHOD OF EXPANDING CORRUGATED TUBE AND MANUFACTURING A HEAT EXCHANGER WITH EXPANSION TUBE", filed Aug. 11, 2010, which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to a method of manufacturing a heat exchanger assembly.

[0004] 2. Description of the Related Art

[0005] Fin plate and tube heat exchanger assemblies are widely used in both industrial and residential capacities to transfer heat from one medium to another, for example, from refrigerant to air. A standard fin plate and tube heat exchanger assembly includes a number of fin plates which are typically fabricated from thin metal, such as aluminum, and arranged parallel to one another. Each fin plate has a number of fin holes or openings through which a heat exchanger tube is inserted. The heat exchanger tube is then expanded to a larger diameter so as to securely lock it into the fin hole, thereby providing good heat exchange contact.

[0006] With the expansion of the diameter of the tube according to known methods, however, there is a corresponding decrease or shrinkage in the length of the tube. Accordingly, manufacturers must factor in the approximate anticipated length reduction of the heat exchanger tube when calculating the length of raw tubing needed to form the final heat exchanger assembly.

[0007] What is needed in the art is a heat exchanger assembly and method of manufacture of a heat exchanger assembly which provides a tight interference fit or lock between the heat exchanger tube and fin plate and, therefore, good heat exchange contact, with minimal or no decrease in the length of the raw tube.

SUMMARY OF THE INVENTION

[0008] The present invention provides a method of manufacturing a heat exchanger coil or assembly including at least one hairpin tube and at least one fin plate.

[0009] According to the method of the present invention, a raw elongate tube having an original outer circumference and a substantially round cross-sectional shape is reconfigured to have a reduced or corrugated cross-sectional shape. The corrugations may be, for example, spiral or longitudinal. The reconfigured or corrugated tube has a first outer circumference or diameter, which is less than the original outer circumference of the raw, uncorrugated tube. A plurality of u-shaped hairpin tubes may be formed by inserting the reconfigured tube into a Hairpin Bender, each u-shaped hairpin tube having a pair of parallel legs. Each leg of the u-shaped hairpin tubes is inserted into or through a predetermined opening in at least one fin plate, for example a plurality of fin plates. Subsequently a plurality of return bends are attached to the u-shaped hairpin tubes, for example by brazing, welding or the use of an adhesive to form a predetermined circuitry. Although the predetermined circuitry has been described as including only u-shaped hairpin tubes and return bends, the circuitry may be formed from any combination of straight tubes, u-shaped hairpin tubes and return bends. Fluid pressure is incrementally applied from a fluid pressure source to an internal channel of the circuitry formed by the corrugated hairpin tubes, straight tubes and/or return bends. To apply the fluid pressure, one end of the circuitry is securely closed or sealed, for example with an end cap. An internal channel of the circuitry is then filled with a fluid, for example, oil, air or refrigerant, which is then placed under pressure by the fluid pressure source. The application of the fluid pressure incrementally pressure inflates the corrugated tube unfolding the corrugations, thereby radially expanding the circuitry to continuously contact the wall of the opening in the fin plate and form a tight heat transfer bond between the circuitry and the wall of the opening(s) in at least one fin plate.

[0010] A heat exchanger assembly includes at least one heat exchanger coil, for example 3 or 4 heat exchanger coils, according to the present invention.

[0011] The substantially round cross-sectional shape of the raw, uncorrugated tube may be, for example, substantially circular or oval-shaped.

[0012] The fluid pressure applied to the heat exchanger coil circuitry may be such that an internal pressure of the circuitry is up to, for example, approximately 2,500 PSI or up to approximately 2,100 PSI.

[0013] The fluid pressure source may, for example, be a hand pump, a hydraulic pump, an electric pump or a gas pump.

[0014] The present invention further provides a method of manufacturing HVAC (Heating Ventalation and Air Conditioning) coils.

[0015] According to the method of manufacturing an HVAC heat exchanger coil, a predetermined number of fin plates, for example at least one or a plurality of fin plates, is selected, the fin plates being enclosed in a fixture with their mounting brackets positioned in precise predetermined locations. A raw, elongate tube having an original circumference and a substantially round cross-sectional shape is reconfigured to have a reduced or corrugated cross-sectional shape. The corrugations may be, for example, spiral or longitudinal. The reconfigured, corrugated tube has a first outer circumference or diameter, which is less than the original outer circumference. A plurality of u-shaped hairpin tubes may be formed by inserting the reconfigured tube in, for example in a Hairpin Bender, and bending. Each u-shaped hairpin tube has a pair of parallel legs and each leg is inserted into or through a predetermined opening in at least one of the fin plates, for example a plurality of fin plates. A final flare may be formed at the open end of each hairpin tube before a plurality of return bends are attached to or coupled with the u-shaped hairpin tubes, for example by brazing, welding or the use of an adhesive to form a predetermined circuitry. Although the predetermined circuitry has been described as including only u-shaped hairpin tubes and return bends, the circuitry may be formed from any combination of straight tubes, u-shaped hairpin tubes and return bends. Fluid pressure is incrementally applied from a fluid pressure source to an internal channel of the circuitry, which is formed by the hairpin tubes, straight tubes and/or return bends. To apply the fluid pressure, one end of the circuitry is securely closed or sealed, for example with an end cap. An internal channel of the circuitry is then filled with a fluid, for example, oil, air or refrigerant, which is then placed

under pressure by the fluid pressure source. As a result of the application of the fluid pressure, the first outer circumference of the corrugated tubing is pressure inflated, unfolding the corrugations and radially expanding the corrugated to equal to or greater than the original outer circumference or diameter of the raw, uncorrugated tube. The incremental fluid inflation and radial expansion of the circuitry results in the tube having continuous contact with a wall of the opening in the fin plate and forms a tight heat transfer bond between the circuitry and the opening in the fin plate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The above-mentioned and other features and advantages of this invention, and the manner of attaining them, will become more apparent and the invention will be better understood by reference to the following description of embodiments of the invention taken in conjunction with the accompanying drawings, wherein:

[0017] FIG. **1** is a sectional view of a portion of a heat exchanger assembly configured in accordance with the present invention;

[0018] FIG. **2** is an exploded view of a heat exchanger assembly according to the present invention;

[0019] FIG. **3** is a perspective view of a heat exchanger assembly according to the present invention; and

[0020] FIG. **4** is a perspective view of a hairpin tube according to the present invention;

[0021] FIG. **4**A is a perspective view of a hairpin tube according to the present invention;

[0022] FIG. **5**A is a cross-sectional view of the corrugated tube of FIG. **4**; and

[0023] FIG. **5**B is a cross-sectional view of the tube of FIG. **4** after pressure inflation.

[0024] Corresponding reference characters indicate corresponding parts throughout the several views. The exemplifications set out herein illustrate embodiments of the invention and such exemplifications are not to be construed as limiting the scope of the invention in any manner.

DETAILED DESCRIPTION OF THE INVENTION

[0025] Referring now to the drawings, and more particularly to FIGS. **4** and **4**A, there is shown hairpin tube **10** which has been formed by reconfiguring pipe or raw tube, which is sized to fit a predetermined opening. The raw pipe or tube has an original outer circumference or diameter and a substantially round cross-sectional shape. The raw tube is reconfigured to have a corrugated or reduced shape, and may subsequently be bent by a Hairpin bender into u-shaped hairpin tube **10** having a pair of parallel legs **12** and an inner channel **14** extending therethrough or, if manufacturing a straight tube, simply cut to length. For purposes of clarity, FIGS. **4** and **4**A illustrate tube **10** as having longitudinal corrugations, however, it is also feasible for tube **10** to have spiral corrugations. The formation of longitudinal corrugations **16** results in tube **10** having a compressed, first outer circumference D**1**, less than original outer circumference of the raw, uncorrugated tube. Longitudinal corrugations **16** may extend the entire length of hairpin tube, as illustrated in FIG. **4**, or may extend along only a portion of hairpin tube **10**, as illustrated in FIG. **4**A. The original outer circumference of the uncorrugated tube may be approximately 20 mm or less, or as small as, for example, approximately 3 mm or less.

[0026] Referring now to FIG. **1**, there is shown, a sectional view of a heat exchanger coil assembly wherein one of parallel legs **12** of hairpin tube **10** having longitudinal corrugations **16** is inserted into or through opening **18** of fin plate **20**. A plurality of return bends (not shown) are coupled with a plurality of hairpin tubes **10** similarly inserted into or through openings **18** in at least one fin plate **20**. Although the heat exchanger coil has been described as including u-shaped hairpin tubes and return bends, it may be formed from any combination of straight tubes, u-shaped hairpin tubes and return bends. Subsequently, longitudinal corrugations **16** are pressure inflated, unfolding the corrugations and radially expanding tube **10** so as to continuously contact a wall of opening **18** of fin plate **20** and form a tight bond or lock with the wall or walls of opening **18** into which it has been inserted. Expanded tube **10** has a second outer circumference or diameter D**2** greater than first outer circumference D**1** of the corrugated tube and equal to or greater than the original outer circumference of the raw, uncorrugated tube.

[0027] The radial expansion of the tube is accomplished by the incremental application of fluidized pressure from fluid pressure source **22** to internal channel **14** of hairpin tube **10**. The method of expansion according to the present invention, provides that one end of the corrugated tube is first securely closed or sealed and internal channel **14** of hairpin tube **10** is subsequently filled with a fluid such as, for example, oil, air or refrigerant, which is then placed under pressure by fluid pressure source **22**. As fluid pressure is incrementally increased, longitudinal corrugations **16** unfold and tube **10** is substantially restored to the original outer circumference of the raw, uncorrugated tube.

[0028] Advantageously, the present invention results in the requirement of a pressurized force for expansion and the avoidance of shrinkage or shortening of the hairpin or straight tube length, thus a predictable and precise dimensional result.

[0029] According to the present invention, the original, uncorrugated, elongate tube may have any substantially round cross-sectional shape having an outer circumference.

[0030] For example, the raw tube may have a substantially oval-shaped cross-sectional shape before it is reconfigured. In this case, the corrugation of the oval-shaped tube, according to the present invention, reduces the original outer circumference of the uncorrugated raw tube to compressed, first outer circumference D**1**.

[0031] Alternatively, the raw tube may have a substantially circular cross-sectional shape before reconfiguration or corrugation. In this case also, the raw tube, sized to fit a predetermined opening, is reconfigured to have a reduced or corrugated shape, resulting in decreased first outer circumference D**1**.

[0032] As described above, according to the method of the present invention, end **24** of hairpin tube **10** is securely sealed or closed, for example with plug **23**, and tube **10** inserted into or through predetermined opening **18** in fin plate **20** and may be inserted through opening **21***a* in end plate **21**. The end of tube **10** may be securely sealed or closed prior to or after inserting tube **10** into or through the predetermined opening **18**. Inner channel **14** of tube **10** is then filled with a fluid, for example, oil, air or refrigerant and the fluid placed under pressure.

[0033] As this fluid pressure is incrementally increased, the internal pressure of tube **10** rises and causes the corrugations to unfold and the original outer circumference or diameter of the raw, uncorrugated tube to be substantially restored, tightly

bonding or locking the tube **10** with at least one wall of opening **18** with minimal force, advantageously without affecting the length of the tube. Fluid pressure may, be applied such that the internal pressure of the tube is up to approximately 2,500 PSI, and could be more or less than this amount of pressure, for example up to approximately 2,100 PSI.

[0034] In accordance with the present invention, the tube may be formed from any number of materials, for example, copper, aluminum, steel or brass, or any alloy thereof.

[0035] The return bends may also be formed from any number of materials including, for example, copper, aluminum, steel or brass, or any alloy thereof.

[0036] The return bends may be coupled with the hairpin tubes and/or straight tubes by any of a number of known methods, including brazing, welding, or the use of adhesives.

[0037] Referring now to FIGS. **2** and **3**, there is shown heat exchanger assembly including a plurality of fin plates **20** (thin, metal plates with a plurality of openings arranged in a specific pattern to assure maximum heat exchange) arranged such that a straight tube and/or parallel legs **12** of hairpin tube **10** configured according to the present invention are inserted into openings **18** of fin plates **20** to form a hairpin and/or straight tube and fin assembly. The entire assembly may include all straight tubes or all hairpins or, alternatively, may include any combination of hairpins and straight tubes, as well as return bends.

[0038] To mechanically bond hairpin tubes **10** and/or straight tubes to fin plate **20**, fin plates **20** may be placed in a fixture for holding fin plates **20** and end sheets **21** in their respective locations. A plurality of return bends **26** are attached or coupled with tubes **10** to form a predetermined circuitry. One end **24** of tube **10** is securely sealed with, for example plug **23**, and the opposite end is filled with fluid and placed under pressure. Pressure is subsequently incrementally applied, thus unfolding longitudinal corrugations **16** and expanding first outer circumference D**1** of corrugated tube **10** to bond fin plate **20** with hairpin and/or straight tube **10**, respectively.

[0039] Advantageously, the unfolding of the corrugations of the hairpins and/or straight tubes according to the present invention, results in a substantial return to the original outer circumference of the raw, uncorrugated tube, resulting in a mechanical locking of tube **10** to fin plates **20** with the application of minimal pressure. This creates a rigid, tight mechanical lock or bond between the straight tubes and/or hair pins with the fin and a very efficient heat transfer bond, making the finished assembly a highly efficient heat transfer coil which can be used in, for example, air conditioning systems and refrigeration systems.

[0040] With respect to the pressure inflation of tube **10**, and unfolding of the corrugations of the tube, as discussed above, inner channel **14** of tube **10** is filled with a fluid, for example, oil, air or refrigerant from pressurized fluid source **22**. Pressurized fluid source **22** may be any of a number of known devices including, for example, a hand pump, hydraulic pump, electric or gas pump and is connected to tube **10** via suitable connection **25**. As this fluid pressure is incrementally increased, the internal pressure of tube **10** causes the corrugations to unfold resulting in tube **10** having second outer circumference D**2**, radially expanding tube **10** and tightly bonding or locking tube **10** with opening **18** of fin plate **20** with minimized force and without affecting the length of the tube. The outer circumference of the tube, resulting from the unfolding and resulting expansion of the heat exchanger tube, is greater than outer circumference D**1** and equal to or greater than the original outer circumference of the raw, uncorrugated tube. As a result of the expansion of heat exchanger tube **10** to correspond with the size of opening **18** in fin plate **20**, a mechanical lock between heat exchanger tube **10**, and thus the predefined circuitry, and fin plates **20** is formed.

[0041] The present invention further provides a method of producing HVAC heat exchanger coils whereby a predetermined number of fin plates is selected, the fin plates then being enclosed in a fixture with their mounting brackets positioned at precise predetermined locations. A raw elongate tube having an original out circumference and a substantially round cross-sectional shape is reconfigured to have a reduced or corrugated cross-sectional shape. The corrugations may, for example, be in the form of spiral or elongate corrugations. The reconfigured or corrugated tube has a first outer circumference or diameter, which is less than the original outer circumference of the raw, uncorrugated tube. A plurality of u-shaped hairpin tubes are formed by bending the reconfigured tube, for example in a Hairpin Bender. Each u-shaped hairpin tube has a pair of parallel legs and each leg is inserted into or through a predetermined opening in at least one of the fin plates, for example a plurality of fin plates. A final flare is formed at the open end of each hairpin tube. Next, a plurality of return bends are attached to the open ends of the hairpin tubes by, for example, brazing, welding, the use of an adhesive or other means. When the HVAC heat exchange coil assembly is completed with respect to the desired circuitry configuration and the remaining access ports to the tubular circuitry are securely attached to a pressure pumping device, pressure expansion of the entire heat exchanger coil is accomplished by closing or sealing the outlet port and applying pressure to the inlet port through a sealed connection to the inlet port. Accordingly, when the HVAC heat exchanger coil is removed from the pressure expansion fixture, it is a fully complete and fully tested heat exchanger. This fully completed HVAC heat exchanger coil may then be bent, if desired, by a coil bending machine while the tubular passages continue to be pressurized, thus insuring minimal, if any, internal tubular restriction due to the HVAC heat exchanger coil forming operation used to reform the coil into a rectangular, circular or other shape to fit cabinetry for a finished air conditioning unit. Although the HVAC heat exchanger coil has been described as including hairpin tubes and return bends, it may be formed from any combination of straight tubes, hairpin tubes and/or return bends.

[0042] The method according to the present invention advantageously allows for the precise placement of hairpin and/or straight tubes and allows for insertion of hairpins and/or straight tubes into fins while the fins and mounting brackets are precisely positioned and enclosed in a holding and alignment fixture. The method according to the present invention further advantageously allows for higher production rates and an improved aesthetic quality coil as a result of minimal handling.

[0043] The method of producing a heat exchanger assembly and/or HVAC heat exchange coil according to the present invention utilizes applied internal pressure for the expansion of corrugated or reduced shape heat exchanger tube to avoid shrinkage or shortening of the tube length, thus a predictable and precise dimensional heat exchanger tube results. Further, due to pressure expansion of the tubes thereby securing the tube to the fin, a good heat transfer is formed between the

hairpin or straight tube outer diameter and the fin collar inner diameter. In addition, the utilization of pressure expansion to produce HVAC heat exchanger coils enables the utilization of hairpin and/or straight tube having smaller original outer diameters, for example, less than 3 mm.

[0044] While this invention has been described with respect to at least one embodiment, the present invention can be further modified within the spirit and scope of this disclosure. This application is therefore intended to cover any variations, uses, or adaptations of the invention using its general principles. Further, this application is intended to cover such departures from the present disclosure as come within known or customary practice in the art to which this invention pertains.

What is claimed is:

1. A method of manufacturing a heat exchanger coil, the method comprising the steps of:

reconfiguring a cross-sectional shape of an elongate tube from a substantially round cross-sectional shape having a first outer circumference to one of a reduced and a corrugated cross-sectional shape having a second outer circumference less than said first outer circumference;

forming a plurality of u-shaped hairpin tubes from said elongate tube, said u-shaped hairpin tubes each having a pair of parallel legs;

inserting each of said parallel legs through a predetermined opening in at least one fin plate;

attaching a plurality of return bends to said u-shaped hairpin tubes to form a predetermined circuitry; and

incrementally applying fluid pressure from a fluid pressure source to an internal channel of said circuitry to incrementally expand said circuitry to form a tight heat transfer bond between said circuitry and at least one wall of said predetermined opening.

2. The method according to claim **1**, wherein an end of said circuitry is sealed prior to said application of said fluid pressure.

3. The method according to claim **1**, wherein said at least one fin plate is a plurality of fin plates.

4. The method according to claim **1**, wherein said substantially round cross-sectional shape is one of substantially circular-shaped and substantially oval-shaped.

5. The method according to claim **1**, wherein said attachment of said plurality of return bends to said u-shaped hairpin tubes is by brazing.

6. The method according to claim **1**, wherein said at least one fin plate is a plurality of fin plates and said predetermined opening is a plurality of predetermined openings in said plurality of fin plates, said predetermined openings being arranged in a predefined arrangement.

7. The method according to claim **1**, wherein said application of fluid pressure one of incrementally expands said reduced shape and unfolds said corrugated shape to re-form said substantially round cross-sectional shape.

8. The method according to claim **1**, wherein said elongate tube is sealed prior to said application of fluid pressure.

9. The method according to claim **1**, wherein said fluid pressure is applied such that an internal pressure of said hairpin tube is up to approximately 2,500 PSI.

10. The method according to claim **9**, wherein said fluid pressure is applied such that said internal pressure of said hairpin tube is up to approximately 2,100 PSI.

11. The method according to claim **1**, wherein said fluid pressure source is one of a hand pump, a hydraulic pump, an electric pump and a gas pump.

12. The method according to claim **1**, wherein a fluid used in said application of said fluid pressure is leak detectable.

13. The method according to claim **1**, wherein each of said pair of parallel legs of said u-shaped hairpin tubes includes an end portion which is not corrugated.

14. The method according to claim **1**, wherein said u-shaped hairpin tube includes a u-shaped portion between said pair of parallel legs, said u-shaped portion not being corrugated.

15. A method of manufacturing a HVAC heat exchanger coil, the method comprising the steps of:

reconfiguring a cross-sectional shape of a plurality of elongate tubes from a substantially round cross-sectional shape having a first circumference to one of a reduced and a corrugated cross-sectional shape having a second circumference less than said first circumference;

bending each of said elongate tubes into a hairpin-shaped tube having a pair of parallel legs;

inserting each of said pair of parallel legs of said hairpin tubes through a predetermined opening in at least one fin plate;

coupling at least one leg of said pair of parallel legs with a return bend to form a predefined circuitry;

incrementally applying fluid pressure from a fluid pressure source to an internal channel of said circuitry to expand said circuitry to said first outer circumference and said substantially round cross-sectional shape and form a tight heat transfer bond between said elongate tube and at least one wall of said predetermined opening.

16. A method of manufacturing a heat exchanger coil, the method comprising the steps of:

reconfiguring a cross-sectional shape of an elongate tube from a substantially round cross-sectional shape having a first outer circumference to a corrugated cross-sectional shape having a second outer circumference less than said first outer circumference;

forming a plurality of tube sections, said tube sections including at least one of straight tubes, u-shaped hairpin tubes and return bends;

forming a predefined circuitry from said at least one of said straight tubes, said u-shaped hairpin tubes and said return bends;

incrementally applying fluid pressure from a fluid pressure source to an internal channel of said circuitry to pressure inflate and radially expand said circuitry to continuously contact a wall of said predetermined opening and form a tight heat transfer bond between said circuitry and said predetermined opening.

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