US 20090159248A1

(19) United States

(12) Patent Application Publication

Mimitz, SR. et al.

(10) Pub. No.: US 2009/0159248 A1

(43) Pub. Date: Jun. 25, 2009

(54) HEAT EXCHANGER, HEAT EXCHANGER TUBE AND METHODS OF MAKING AND USING SAME

(76) Inventors: **Timothy E. Mimitz, SR.**, Williamsburg, MA (US); **Sunil Raina**, Manchester, CT (US); **Fred C. Scheideman**, Windsor Locks, CT (US); **Floyd J. Lewis, JR.**, Longmeadow, MA (US)

Correspondence Address:
ALIX YALE & RISTAS LLP
750 MAIN STREET, SUITE 1400
HARTFORD, CT 06103 (US)

(21) Appl. No.: **12/316,715**

(22) Filed: **Dec. 16, 2008**

Related U.S. Application Data

(60) Provisional application No. 61/008,807, filed on Dec. 21, 2007.

Publication Classification

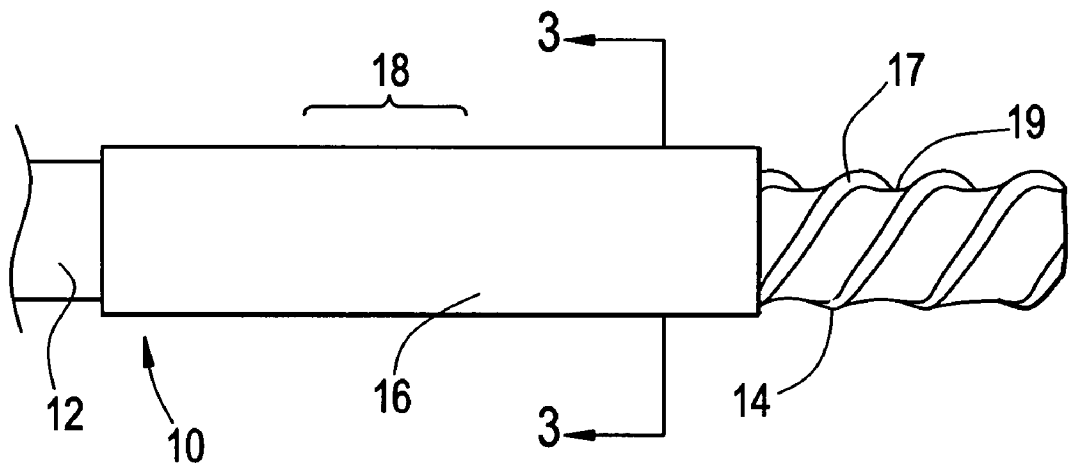
(51) **Int. Cl.**

F28D 7/10	(2006.01)
F28F 1/00	(2006.01)
B21D 53/02	(2006.01)

(52) **U.S. Cl.** **165/154**; 165/177; 29/890.03

(57) **ABSTRACT**

A heat exchanger tube is disclosed herein comprising a first portion, a twisted portion, and a transition portion between the first portion and the twisted portion. The transition portion includes a reinforcing sleeve. A heat exchanger formed from the tube and a method of forming a heat exchanger tube also are disclosed. The tube is useful in making a heat exchanger configured to operate at high pressures without mechanical failure.



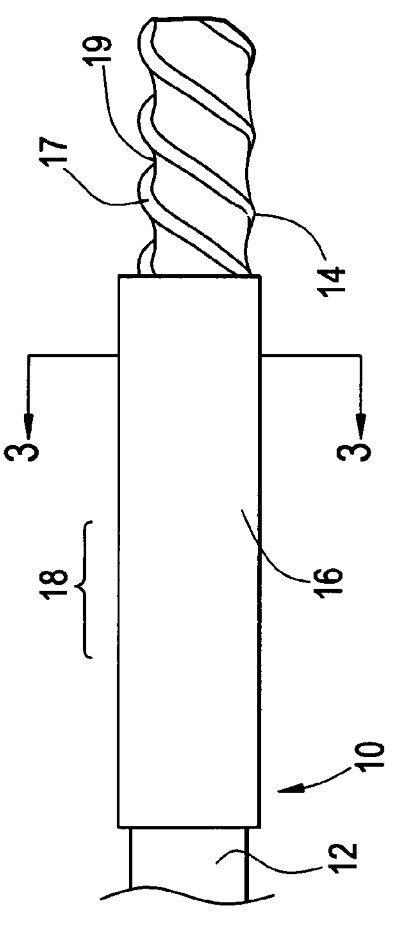


FIG. 1

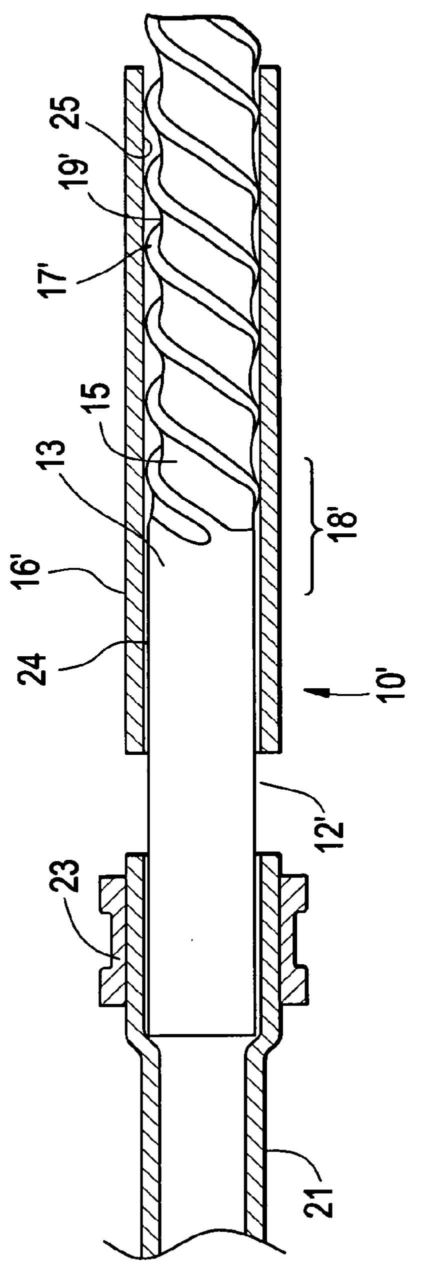


FIG.2

FIG. 3

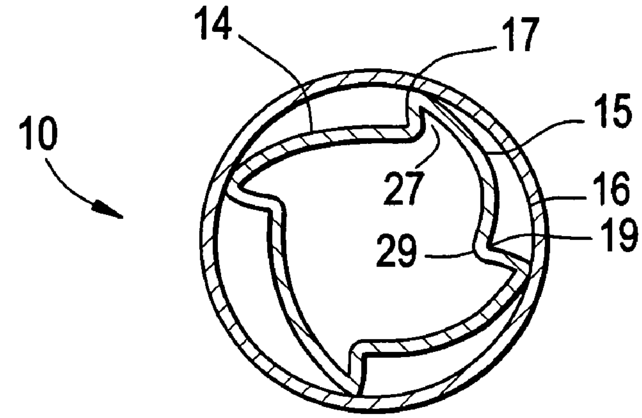


FIG. 4

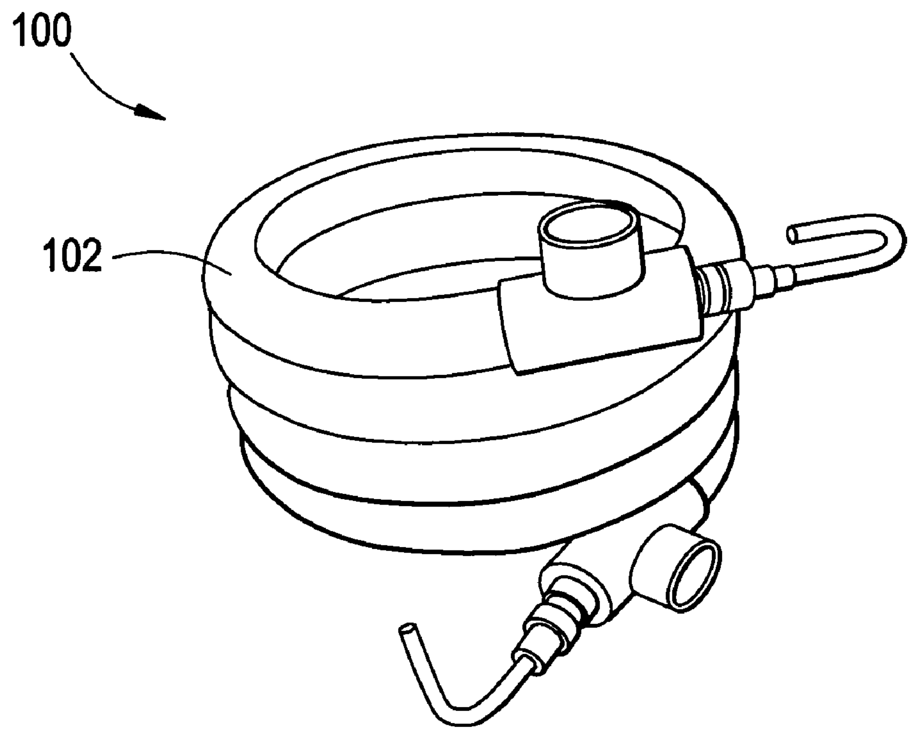
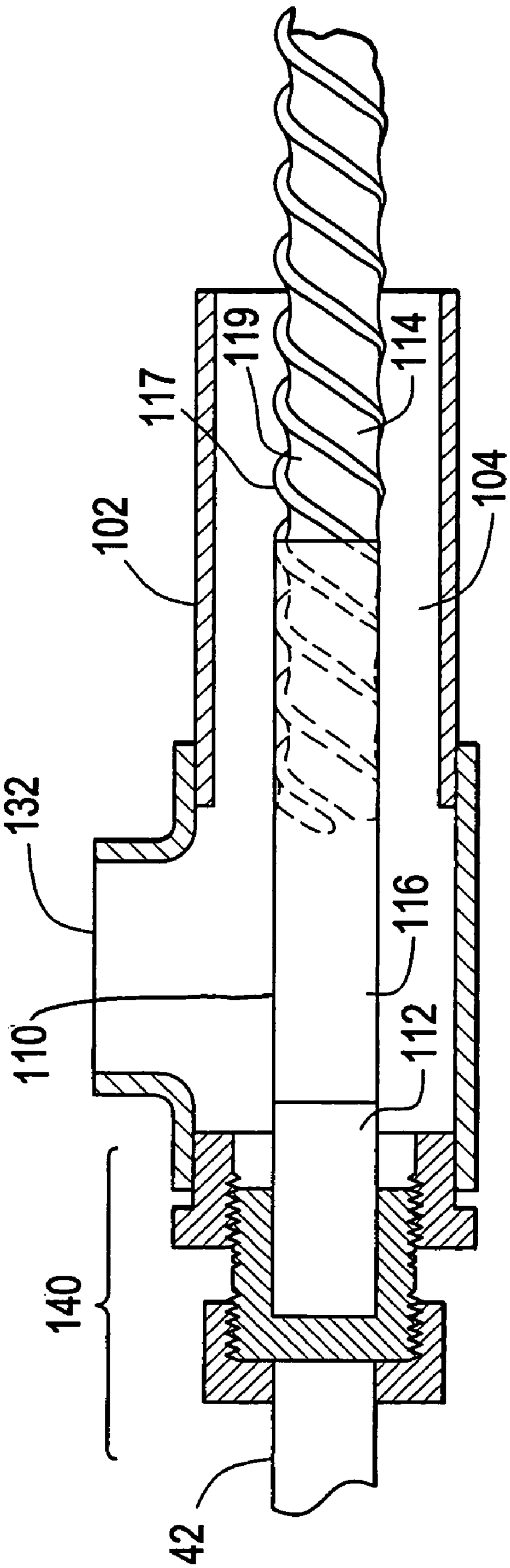


FIG. 5



HEAT EXCHANGER, HEAT EXCHANGER TUBE AND METHODS OF MAKING AND USING SAME

RELATED APPLICATIONS

[0001] This application claims priority from U.S. Provisional Patent Application No. 61/008,807 filed Dec. 21, 2007.

BACKGROUND

[0002] Tube-in-tube heat exchangers are used in a variety of applications for transferring heat from one fluid to another. Particular configurations of tube-in-tube heat exchangers are described in U.S. Pat. Nos. 5,004,047 and 6,012,514.

[0003] Traditionally, tube-in-tube heat exchangers used for swimming pool heat pumps had CuNi inner tubes enclosed in a copper or steel jacket. Later, titanium alloys were used to form the inner tubes in order to provide improved chlorine resistance, and the outer shells were made of polyvinyl chloride.

[0004] Currently, swimming pool heat pumps are available that have heat exchangers formed from an inner tube of twisted titanium in a plastic polyvinyl chloride jacket. The heat exchangers are suitable for use with R-22 refrigerant. The twisted titanium tube is connected to a copper tube transition with a lock ring connector.

[0005] It would be useful to further improve the efficiency of heat exchangers used in corrosive environments, including but not limited to swimming pool heat exchangers.

SUMMARY

[0006] One embodiment is a heat exchanger tube comprising a first portion, a twisted portion, and a transition portion between the first portion and the twisted portion, the transition portion including a reinforcing sleeve.

[0007] Another embodiment is a heat exchanger comprising an outer tube and an inner tube defining an annular opening therebetween, the inner tube including a first portion, a twisted portion, and a transition portion between the first portion and the twisted portion including a reinforcing sleeve formed thereon, the inner tube being configured to withstand a hydrostatic test pressure of at least 2600 psig for at least 2 minutes without mechanical failure.

[0008] Yet another embodiment is a heat exchanger comprising an outer tube and an inner tube defining an annular opening therebetween, the inner tube including a first portion, a twisted portion, and a transition portion between the first portion and the twisted portion including a reinforcing sleeve formed thereon, the inner tube being configured to pass a fatigue test of 250,000 cycles between 118 psig and 418 psig at a rate of 0.5 cycles/second without mechanical failure.

[0009] Another embodiment is a method of making a heat exchanger tube comprising forming a inner tube comprising a first portion, a twisted portion, and a transition portion between the first portion and the twisted portion, and forming a reinforcing sleeve over the transition portion.

[0010] Yet another embodiment is a heat exchanger comprising an inner tube comprising a first portion, a twisted portion, and a transition portion between the first portion and the twisted portion including reinforcing sleeve, and an outer tube or shell surrounding the inner tube.

[0011] A further embodiment is a method of extending the useful life of a heat exchanger tube comprising a first portion connected to a twisted portion, the method comprising forming a reinforcing sleeve over the connection between the first portion and the twisted portion.

[0012] Yet another embodiment is a method of forming a heat exchanger tube capable of use at test pressures up to at least 2600 psig, comprising forming a heat exchanger tube comprising a first portion, a twisted portion, and a transition portion between the first portion and the twisted portion, and forming a reinforcing sleeve over the transition portion.

[0013] Another embodiment is a method of forming a heat exchanger tube capable of use at operating pressures up to at least 500 psig, comprising forming a heat exchanger tube comprising a first portion, a twisted portion, and a transition portion between the first portion and the twisted portion, and forming a reinforcing sleeve over the transition portion.

[0014] A further embodiment is a method of protecting a twisted heat exchanger tube from fluid impingement on its outer surface, comprising forming a reinforcing sleeve over the upstream part of the twisted portion of the tube.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] FIG. **1** is a side view of a sleeved tube segment in accordance with certain embodiments.

[0016] FIG. **2** is a side view of a tube segment with the outer layers cut away to show the transition portion beneath the sleeve.

[0017] FIG. **3** is a section view of the sleeved tube segment of FIG. **1**.

[0018] FIG. **4** is a perspective view of a heat exchanger tube containing the sleeved tube segment of FIG. **1**.

[0019] FIG. **5** is a side view of a segment of the heat exchanger tube with the outer layer cut away to show the sleeved tube segment.

DETAILED DESCRIPTION

[0020] A new and improved heat exchanger tube has been developed that enables environmentally favorable and efficient refrigerants to be used in corrosive environments, including in the presence of chlorinated swimming pool water. The new heat exchanger tube can be used at pressures up to 500 psig or more, or 600 psig or more, and is particularly useful when the pressure difference on opposite sides of the tube wall is 300 psig or more. The tube can be used with R-410A refrigerant, which has a zero Ozone Depleting Potential, as well as other refrigerants requiring high pressures. The new tube can be fabricated in a variety of sizes and shapes. Typically, the twisted tube is coiled and is enclosed a hard coil-shaped tube made of plastic or another suitable material. The coils can have various diameters, and various numbers of turns per linear meter.

Definitions

[0021] As used herein, a "twisted portion" of a tube is a portion that has improved heat transfer resulting from increased surface area per unit length of the tube by twisting the tube. A twisted portion of tube material has one or more visible flutes on one or both of its inner and outer surfaces. As used herein, a "smooth portion" and a "straight portion" of a tube are non-twisted portions of a tube. As used herein, "mechanical failure" refers to a fracture or rupture of the tube.

[0022] Referring first to FIG. **1**, a side view of a tube is shown and is generally designated as **10**. The tube **10** includes a first portion **12** (which usually but not necessarily is a non-twisted or straight portion), a twisted portion **14** and a transition portion **18** between the straight portion **12** and the twisted portion **14**. A reinforcing sleeve **16** is mounted over the transition portion **18**. The reinforcing sleeve **16** usually is formed from straight tube material, however other configurations of tube material can be used.

[0023] The twisted portion **14** of the tube **10** includes a spiraling flute **17** and a corresponding valley **19**, both of which spiral along the length of the twisted portion **14** of the tube **10**. Tube configurations having multiple flutes and valleys also can be used.

[0024] The first portion **12** and twisted portion **14** usually comprise titanium and often are made from a titanium alloy. The sleeve **16** typically is formed from titanium or a titanium alloy. The sleeve prevents mechanical failure of the twisted portion **14** of the tube material at and near the connection with the first portion **12** of the tube material when the heat exchanger is operated at a 500 or 520 psig (or higher) working pressure. The sleeve also prevents mechanical failure of the twisted portion **14** of the tube material at and near the connection with the first portion **12** of the tube material when the tube **10** is tested at a test pressure of, e.g. 2500-3000 psig for 2-6 minutes.

[0025] For a swimming pool or spa heat exchanger, the sleeve typically has an outer diameter in the range of about 0.75 inch to 1.25 inch, and a length of about 5-7 inches. It is noted that tubing with larger and smaller dimensions can be used, and that sleeves of longer and shorter lengths can be used. The flutes typically have a peak-to-valley height of about 0.145" to 0.150" and a length of approximately 0.375" per rotation. The twisted portion of the tube often has an average wall thickness in the range of 0.018" to 0.025". The thinness of the tube wall provides for effective heat transfer between the fluids on opposite sides of the tube wall. The ratio of the length to the outer diameter of the sleeve typically, but not necessarily, is in the range of 6-8, and often is in the range of 6.5 to 7.0.

[0026] FIG. **2** shows the portion of a tube **10'** that is connected to other tubing. In this embodiment, the first portion **12'** is connected to a second tube **21** which typically is formed from a different material, such as copper. The second tube **21** and a connector **23** typically are positioned beside (not within) an outer heat exchanger tube (not shown). The connector **23** typically comprises brass or another suitable material and connects the first portion **12'** to the second tube **21**.

[0027] In FIG. **2**, the sleeve **16'** is cut away to show further details of the transition portion **18'**. In the particular embodiment shown in FIG. **2**, a first section **13** of the transition portion **18'** is straight and a second section **15** is twisted. The first and second sections **13** and **15** typically are part of a continuous piece of tube material. In the embodiment shown in FIG. **2**, about one quarter of the length of the tube material covered by the sleeve **16'** is straight tube, and about three quarters of the length of tube material covered by the sleeve **16'** is twisted tube. Inner wall **25** of sleeve **16'** is adjacent to the flute **17'**. The inner wall **25** of sleeve **16'** is also configured to fit closely around the outer wall **24** of first portion **12'**. In embodiments in which the twisted portion **14'** of the tube **10'** has a larger outer diameter than the first portion **12'**, the sleeve will be slightly tapered to accommodate these dimensions.

[0028] FIG. **3** shows a cross-sectional view of the tube **10** of FIG. **1** taken along line **3-3** of FIG. **1**. The flute **17** on the outer surface of the twisted portion **14** of the second section **15** forms a complementary channel **27** inside the twisted portion **14** of the tube **10**. The valley **19** on the outer surface of the twisted portion forms a corresponding, inwardly projecting portion **29** inside the twisted portion **14** of the tube **10**. This configuration promotes mixing on both sides of the twisted tube wall.

[0029] FIGS. **4** and **5** show a tube-in-tube heat exchanger **100**. The heat exchanger **100** has a helically coiled outer tube **102** which contains an inner tube **110**, which preferably but not necessarily is coaxial with the outer tube **102**, forming an annular opening **104** therebetween configured for flow of a heat transfer fluid therethrough. A sleeve **116** is positioned over the transition between a first portion **112** and a twisted portion **114** of the tube **110**. The twisted portion **114** has a flute **117** and a valley **119**. The inner tube **110** generally has the configuration of the tube shown in FIG. **1**. The heat exchanger **100** has a water inlet **132**, a water outlet (not shown), a refrigerant inlet section with a refrigerant inlet (not shown), and a refrigerant outlet section **140** with a refrigerant outlet **142**.

[0030] The outer tube **102** can be made of a material that is resistant to corrosion by the fluid that flows in the annular opening **104**. When the fluid is chlorinated water, a hard plastic material such as polyvinyl chloride can be used. The reinforcing sleeve provides for use of the tube in a tube-in-tube heat exchanger in which the pressure difference between the inside and the outside of the tube is at least 300 psi. or at least 450 psi, or at least 550 psi. When a refrigerant such as R-410A is used, the pressure on the inside of the inner tube typically reaches a maximum of 600 psig and the pressure on the outside of the inner tube typically is in the range of 25 to 100.

[0031] Various tests were conducted during the process of forming the new heat exchanger tubing. Test procedures and results are shown in Examples 1-3. The examples are included to illustrate features of the invention but are not intended to be limiting.

EXAMPLE 1

Fatigue Testing

[0032] Seven different sets of tubes having a straight portion and a twisted portion (Samples 1-6 and 9) were tested using fatigue test UL 1995 to determine their suitability for use in a heat exchanger operating with R-410A refrigerant. Two sets of tube material that only contained smooth tubing also were tested (Samples 7-8). The twisted tubes were formed from a titanium alloy and had the following general dimensions: ⅞ inch outer diameter, 0.020 wall thickness along the straight portion, and 0.020 average wall thickness along the twisted portion. The fluted portion had an outer diameter of about 0.810-0.850, a height of about 0.145 from flute to valley as measured on the outer wall, and approximately 33 turns per linear foot. According to the literature, the titanium alloy used in making the tube material has an ultimate tensile strength of approximately 65 ksi, a yield strength of approximately 50 ksi and a nominal composition typical of type 2 titanium. The smooth tubes had the same composition as the twisted tube and the same dimensions as the smooth portion of the twisted tubes.

[0033] In the fatigue test (as per UL 1995), the tubes were cycled between 118 psig and 418 psig for 250,000 cycles. Hydraulic oil was used as the test fluid. The outer surface of the tube was maintained at atmospheric pressure. To pass the test, no failure can occur. The hydraulic system was controlled by a servo valve to pressurize the test articles. The system included a hydraulic pump, interconnecting piping, on/off valves, servo valve, filters, accumulator and PLC electronic controls. UL 1995 requires that the high and low pressure in any cycle be maintained for at least 0.10 seconds. Tests were run at around 0.5 cycles/sec or 2 sec/cycle.

[0034] As is shown on Table 1 below, none of the twisted tube Samples 1-6 and 9 passed the fatigue test. Both of the smooth tube Samples 7-8 passed the test, showing that the non-twisted material is acceptable for use at the pressures required for R-410A refrigerant.

EXAMPLE 2

Hydrostatic Strength Testing

[0035] Five different types of tubes having a straight portion and a twisted portion (Samples 10-14) were tested using a hydrostatic strength test to determine their suitability for use in a heat exchanger operating with R-410A refrigerant. The twisted tubes were formed from a titanium alloy and had the following general dimensions: ⅞ inch outer diameter, 0.020" wall thickness along the straight portion, and 0.020" average wall thickness along the twisted portion. The fluted portion had an outer diameter of about 0.810-0.850", a height of about 0.134" from flute to valley as measured on the outer wall, and approximately 33 turns per lineal foot. According to the literature, the titanium alloy used in making the tube material has an ultimate tensile strength of approximately 65 ksi, a yield strength of approximately 50 ksi and a nominal composition typical of type 2 titanium.

[0036] To pass the hydrostatic strength test, a tube is required to withstand 5 times the desired working pressure for a minimum of 2 minutes. Thus, for a desired working pressure of 520 psi the test is run at 2600 psi, and for a desired working pressure or 600 psi the test is run at 3000 psi. Pressure outside the tube was atmospheric. Water was used as the fluid in the high pressure test.

[0037] As is shown on Table 1 below, none of Samples 10-14 passed the hydrostatic strength test at 2600 psig, thus showing the difficulty in using twisted tube material in high pressure environments.

TABLE I

Task	Required Procedure/Method	Task Description	Acceptance Criteria	Location	Samples Tested	Test Result
1	Fatigue Test-UL 1995 R410A	Turbotec Laboratory TR2004-134	250K cycles without failure	Turbotec Inc.	3	Fail
2	Fatigue Test-UL 1995 R410A	Turbotec Laboratory TR2004-135	250K cycles without failure	Turbotec Inc.	3	Fail
3	Fatigue Test-UL 1995 R410A	Turbotec Laboratory TR2006-091	250K cycles without failure	Turbotec Inc.	3	Fail
4	Fatigue Test-UL 1995 R410A	Turbotec Laboratory TR2006-101	250K cycles without failure	Turbotec Inc.	3	Fail
5	Fatigue Test-UL 1995 R410A	Turbotec Laboratory TR2006-127	250K cycles without failure	Turbotec Inc.	3	Fail
6	Fatigue Test-UL 1995 R410A	Turbotec Laboratory TR2006-142	250K cycles without failure	Turbotec Inc.	3	Fail
7	Fatigue Test-UL 1995 R410A	Turbotec Laboratory TR2006-177	250K cycles without failure	Turbotec Inc.	3	Pass
8	Fatigue Test-UL 1995 R410A	Turbotec Laboratory TR2006-178	250K cycles without failure	Turbotec Inc.	3	Pass
9	Fatigue Test-UL 1995 R410A	Turbotec Laboratory TR2006-192	250K cycles without failure	Turbotec Inc.	3	Fail
10	Hydostatic Pressure Tube Side R410A	Turbotec Laboratory TR2006-197	2600 psig	Turbotec Inc.	2	Fail
11	Hydostatic Pressure Tube Side R410A	Turbotec Laboratory TR2006-206	2600 psig	Turbotec Inc.	2	Fail
12	Hydostatic Pressure Tube Side R410A	Turbotec Laboratory TR2006-214	2600 psig	Turbotec Inc.	2	Fail
13	Hydostatic Pressure Tube Side R410A	Turbotec Laboratory TR2006-220	2600 psig	Turbotec Inc.	2	Fail
14	Hydostatic Pressure Tube Side R410A	Turbotec Laboratory TR2007-007	2600 psig	Turbotec Inc.	2	Fail
15	Hydostatic Pressure Tube Side R410A	Turbotec Laboratory TR2007-024	3000 psig	Turbotec Inc.	2	Fail
16	Hydostatic Pressure Tube Side R410A	Turbotec Laboratory TR2007-039	3000 psig	Turbotec Inc.	2	Pass
17	Fatigue Test-UL 1995 R	Turbotec Laboratory TF2007-041	250K cycles without failure	Turbotec In	3	Pass

EXAMPLE 3

Twisted Tube with Reinforcing Sleeve

[0038] Reinforcing sleeves made of type 2 titanium alloy having an inner diameter of about ⅞ inch and a length of 6 inches were placed (swaged) around the transition point from smooth tubing to twisted tubing of several samples of the same type of tube material of the same dimensions as was used in Example 2. The tubes with the reinforcing sleeves were subjected to the hydrostatic strength test described above in Example 2 using water as the high pressure test fluid. The inside of the twisted tube was brought to a pressure of 2,600 psig, and this pressure was maintained for 2 minutes. Subsequently, the pressure was increased to 2,700 psig for 2 additional minutes, and the pressure was then increased to 3,000 psig for 2 more minutes. The outer surface of the tube was at atmospheric pressure. The twisted tube was then examined for failures.

[0039] For Sample set **15** (TR 2007-024) which included the reinforcing sleeve, no failures were detected at 2600 psig but failure occurred at 3000 psig. For tube sample TR 2007-039, which included both a reinforcing sleeve and a tight fit reducer bushing positioned around the plain end, no failure occurred even at 3000 psig.

EXAMPLE 4

[0040] The same type of tube samples as were used in Example 3, Sample 16, were subjected to a fatigue test in accordance with UL1995, described above in Example 1, using hydraulic oil as the test fluid. The set of samples passed two full rounds of testing without any failures. The results are shown in Table 1 as Sample 17 (Example TR-2007 041).

[0041] An important advantage of the embodiments disclosed herein is that the twisted tubes can be used in conjunction with refrigerants that replace HCFCs. Nonlimiting examples of refrigerants that can be used with the embodiments described herein are provided below on Table 2.

TABLE 2

Refrigerants			
Substitute (Name Used in the Federal Register)	Trade Name	Refrigerant Being Replaced	Retrofit/ New
HFC-134a		22	N
THR-03		22	N
ISCEON 59, NU-22, R-417A	Isceon 59, NU-22	22	R, N
R-410A, R-410B	AZ-20, Suva 9100, Puron	22	N
R-407C	Suva 9000, Klea 66	22	R, N
R-507, R-507A	AZ-50	22	R, N
NU-22	NU-22	22	R, N
Ammonia Absorption		22	N
Evaporative/Desiccant Cooling		all HCFCs	N
R-404A	HP62	22	R, N
R-125/134a/600a (28.1/70.0/1.9)		22	R, N
RS-44	RS-44	22	R, N
R-421A	Choice R421A	22	R, N
R-422D	ISCEON MO29	22	R, N

TABLE 2-continued

Refrigerants			
Substitute (Name Used in the Federal Register)	Trade Name	Refrigerant Being Replaced	Retrofit/ New
R-424A	RS-44	22	R, N
R-125/290/134a/600a (55.0/1.0/42.5/1.5)	ICOR AT-22	22	R, N
R-422C	ICOR XLT1	22	R, N
R-422B	ICOR XAC1	22	R, N
KDD5	KDD5	22	R, N
RS-45 (ASHRAE proposed designation: R-434A)	RS-45	22	R, N
R-125/290/134a/600a (55.0/1.0/42.5/1.5)	ICOR AT-22	22	R, N
R-422B	XAC1, NU-22B	22	R, N
R-422C	XLT1	22, 402A, 402B, 408A	R, N

Key:
R = Retrofit Uses,
N = New Uses

[0042] It will be appreciated that features disclosed above and other features and functions, or alternatives thereof, may be desirably combined into many other different systems or applications. Furthermore, currently unforeseen or unanticipated alternatives, modifications, variations or improvements therein may be subsequently made by those skilled in the art which are also intended to be encompassed by the following claims.

What is claimed is:

1. A heat exchanger tube comprising a first portion, a twisted portion, and a transition portion between the first portion and the twisted portion, the transition portion including a reinforcing sleeve.

2. The heat exchanger tube of claim **1**, wherein the reinforcing sleeve is positioned over the transition portion.

3. The heat exchanger tube of claim **2**, wherein the first portion comprises straight tube material.

4. The heat exchanger tube of claim **1**, wherein the first portion, twisted portion and transition portion comprise titanium.

5. The heat exchanger of claim **4**, wherein the reinforcing sleeve comprises titanium.

6. A heat exchanger comprising an outer tube and an inner tube defining an annular opening therebetween, the inner tube including a first portion, a twisted portion, and a transition portion between the first portion and the twisted portion including a reinforcing sleeve formed thereon, the inner tube being configured to withstand a hydrostatic test pressure of at least 2600 psig for at least 2 minutes without mechanical failure.

7. The heat exchanger of claim **6**, wherein the heat exchanger is configured to receive a first fluid in the inner tube and second fluid in the annular portion, and the reinforcing sleeve enables to heat exchanger to operate with a pressure difference of at least 300 psi between the first and second fluids.

8. The heat exchanger of claim **6**, wherein the inner tube is configured to withstand a hydrostatic test pressure of at least 3000 psig for at least 2 minutes without mechanical failure.

9. The heat exchanger of claim **6**, wherein the outer tube is coiled.

10. The heat exchanger of claim **6**, wherein the heat exchanger contains a refrigerant fluid in the inner tube and a second fluid in the annular space between the inner tube and outer tube.

11. The heat exchanger of claim **10**, wherein the refrigerant is at least one of R410A, R-410b, R-417a, R-134a and R-407a.

12. The heat exchanger of claim **10**, wherein the second fluid comprises water.

13. The heat exchanger of claim **10**, wherein the second fluid comprises chlorinated water.

14. A heat pump comprising the heat exchanger of claim **6**.

15. A heat exchanger comprising an outer tube and an inner tube defining an annular opening therebetween, the inner tube including a first portion, a twisted portion, and a transition portion between the first portion and the twisted portion including a reinforcing sleeve formed thereon, the inner tube being configured to pass a fatigue test of 250,000 cycles between 118 psig and 418 psig at a rate of 0.5 cycles/second without mechanical failure.

16. The heat exchanger of claim **15**, wherein the heat exchanger is configured to receive a first fluid in the inner tube and second fluid in the annular portion, and the reinforcing sleeve enables to heat exchanger to operate with a pressure difference of at least 300 psi between the first and second fluids.

17. A method of making a heat exchanger tube comprising:

forming a inner tube comprising a first portion, a twisted portion, and a transition portion between the first portion and the twisted portion, and

forming a reinforcing sleeve over the transition portion.

18. The method of claim **17**, further comprising disposing the inner tube and reinforcing sleeve in an outer tube to form an annular opening between the inner tube and the outer tube.

19. The method of claim **17** wherein the inner tube and the reinforcing sleeve comprise titanium.

20. The method of claim **17** wherein the first portion, twisted portion and transition portion are formed from a continuous segment of tube material.

21. The method of claim **17** wherein the transition portion includes a section of straight tube material and a section of twisted tube material, and the reinforcing sleeve is configured to protect a portion of the section of twisted tube material from fluid impingement.

* * * * *