United States Patent [19]

Dreksler

[11] **3,877,518**

[45] **Apr. 15, 1975**

[54] **HEAT EXCHANGE COIL**

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[22] Filed: **Mar. 19, 1971**

[21] Appl. No.: **125,988**

[52] **U.S. Cl.** **165/150;** 165/151; 165/178; 285/DIG. 16; 285/157

[51] **Int. Cl.** **F28f 9/08**

[58] **Field of Search** 165/143, 144, 172, 173, 165/178; 285/DIG. 16, 157, 287, 332

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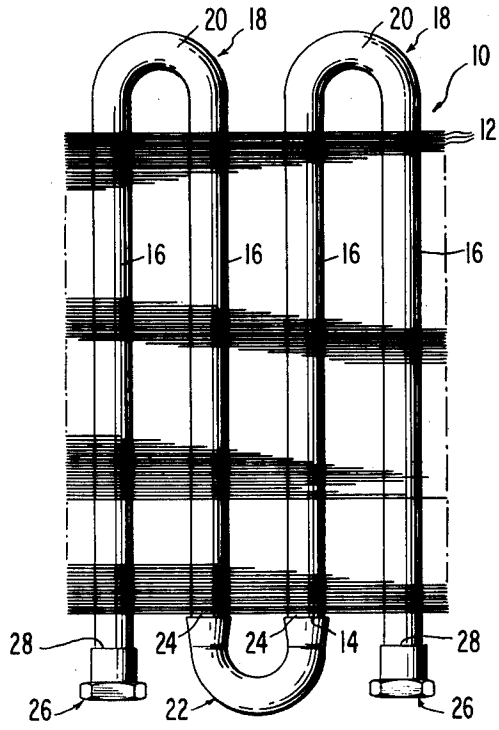
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Attorney, Agent, or Firm—Sughrue, Rothwell, Mion, Zinn & Macpeak

[57] **ABSTRACT**

Aluminum tubes particularly useful in forming heat exchange coils are joined together by first flaring and necking respective tube ends to define tapered mating surfaces to insure maximum wetting of both surfaces by the epoxy which bonds the tubes together when the epoxy coated male tube is inserted axially within the female tube.

3 Claims, 6 Drawing Figures



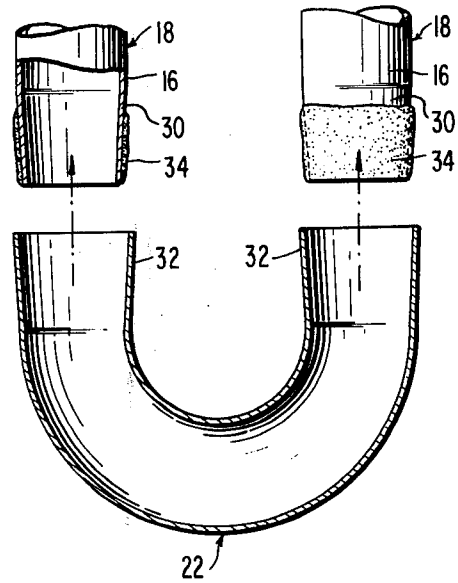


FIG. 1

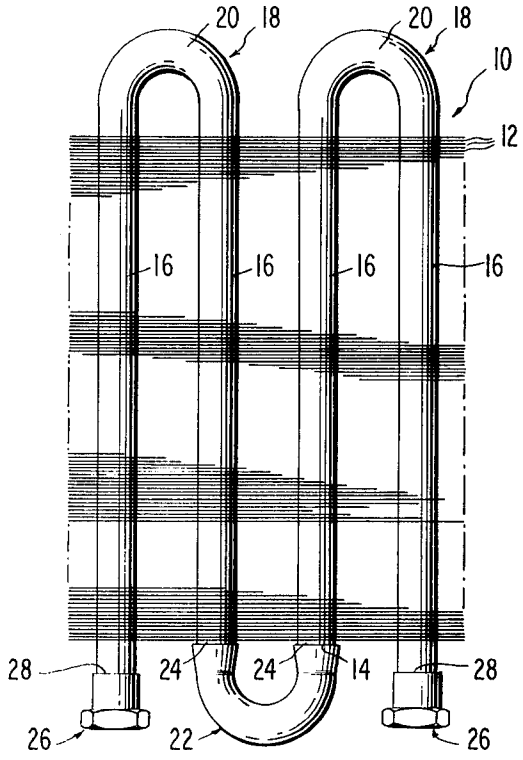


FIG. 2

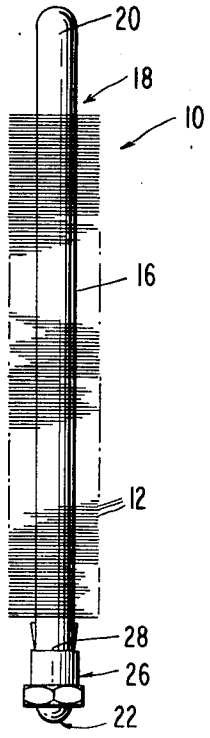


FIG. 3

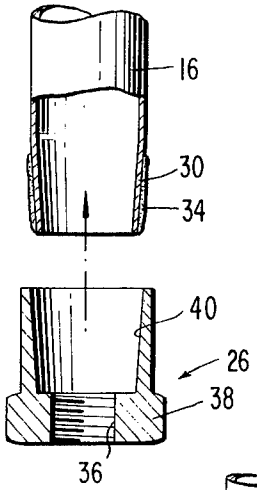


FIG. 4

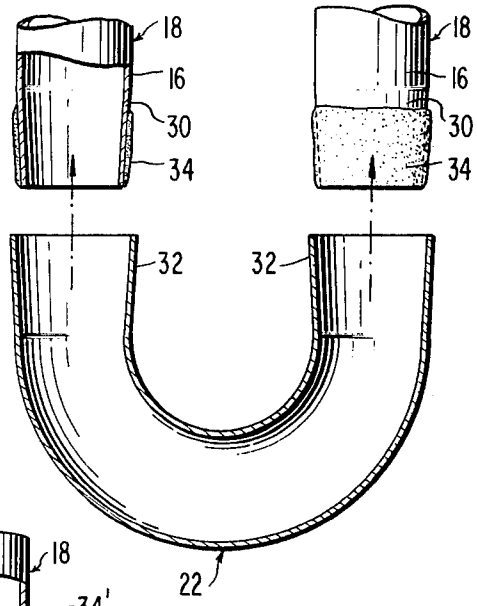


FIG. 5

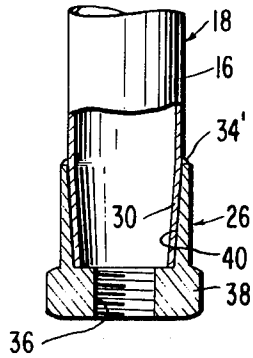
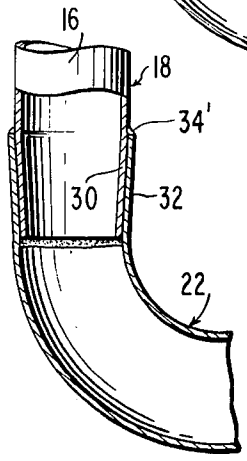


FIG. 6



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HEAT EXCHANGE COIL

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to the formation of high integrity joints between aluminum tubes and, more particularly, to the formation of a high integrity epoxy joint between tubular aluminum members particularly useful in the refrigeration field.

2. Description of the Prior Art

Heat exchange coils of the fin and tube type have been manufactured in the past by utilizing thin, extruded tubes of metals having high thermal conductivity, in which case sections of tubes, after insertion through holes within a plurality of longitudinally spaced fins, are coupled together to effect a serpentine flow path through the radiating fins and may in turn, have threaded fittings and the like coupled to the extreme ends of the serpentine coil for attachment to a liquid source and drain. In the past, heat exchangers of this type have been formed of either copper or aluminum tubes in which case the joints between tube sections or between the tubes and the end fittings were formed generally by various brazing processes. Not only is the assembly of aluminum parts and the subsequent brazing, time consuming and therefore relatively costly and complex, but the brazing operation is highly critical with low production rates due to the need for complete rinse of the brazing flux, and a relatively high percentage of leaks occurring at the brazed joints. The presence of one or more leaks requires rebrazing of the assembly in the leak area to eliminate the same. While rebrazing and soldering allows some of the units to be made leak-free, certain assemblies have to be discarded, either because of the impossibility to reach the area of the leak or to successfully eliminate the same.

SUMMARY OF THE INVENTION

The present invention is directed to a method of forming a high integrity adhesive joint between tubular aluminum members and, in particular, to an aluminum heat exchanger coil employing epoxy adhesive joints between tubular aluminum components. The method involves flaring the ends of one tubular member to define an outwardly tapering female mating surface portion and correspondingly necking the coupling end of the other tubular member to define a corresponding inwardly tapered female mating surface portion. An epoxy adhesive is supplied to at lease one of the mating surface portions, and the male tubular member is axially inserted into the female member until the epoxy uniformly wets both mating surfaces, whereupon the epoxy is cured to effect the high integrity bond. Preferably, the axial insertion is completed when a small bead of epoxy is uniformly extruded completely around the periphery of the exposed edge of the flared female tubular member.

The invention is particularly applicable to a heat exchange coil of the type which includes a plurality of adjacently positioned hairpin-shaped tubes, commonly supported by a plurality of longitudinally spaced heat exchange fins, with the tubes extending through holes formed within the fins. The ends of two separate tubes are joined by a U-shaped return bend tube to effect a serpentine configuration to the aluminum tube heat exchanger. The improvement lies in flaring the ends of the hairpin-shaped tubes and necking the ends of the return bend tubes or vice versa prior to applying an epoxy adhesive bond between the coplanar mating surfaces of the tube ends to effect a high integrity seal by curing the epoxy subsequent to coupling of the return bends to the exposed ends of the hairpin-shaped tubes. The extreme tube ends of the assembly may carry threaded couplings which in turn have cooperating tapered surfaces facing the tube ends for achieving a high integrity epoxy seal therebetween.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a plan view of a heat exchanger coil incorporating the high integrity epoxy joint between tubular aluminum members forming components of the same.

FIG. **2** is a side elevation of the embodiment of FIG. **1.**

FIGS. **3** and **4** are exploded sectional views of portions of the heat exchanger coil of FIG. **1** illustrating how the epoxy joints are to be completed by the method of the present invention.

FIGS. **5** and **6** are sectional views of the coil portions of FIGS. **3** and **4,** respectively, after curing of the epoxy joints.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention is exemplified in a preferred embodiment in terms of the heat exchange coil **10,** FIG. **1,** which comprises essentially a plurality of longitudinally spaced outer fins in the form of rectangular plates **12** of aluminum or other high thermal conductive material, the fins having circular openings **14** at laterally spaced positions which receive the straight portions **16** of, in this case, a pair of hairpin aluminum tubes **18.** The straight tube portions **16** are joined by a semi-circular connecting portion **20** and the hairpin tubes **18** are joined at one end by a U-shaped return bend tube **22** and define with tubes **18,** joints indicated generally at **24.** The four tube single row coil assembly **12** therefore consists essentially of the two hairpin tubes **18** and the return bend tube **22.** The outside straight tube portions **16** terminate at the same end of the assembly **12** as the return bend tube **22** in a pair of threaded tubular aluminum couplings **26** and the straight tube sections **16** define with couplings **26** joints **28.** The aluminum tubes **18** and **22** are preferably formed of 3003 Alluminum Alloy or the equivalent, of zero temper, nominal three-quarter inch OD, 0.028 inch wall thickness and being formed to accommodate the return bend tube **22** of the same material and size. The joints **24** between the return bend tube **22** and the hairpin tubes **18** are in the form of a taper of wedge-like configuration, with the return bend tube **22** in this case forming the female part. The resulting overlap wedge-joint at **24** is covered with a single part epoxy high-temperature structural adhesive such as Type 2214 manufactured by Minnesota Mining and Manufacturing Company or the equivalent, after degreasing of the mating surfaces with tri-chlorol-ethylene or the like. The epoxy adhesive is paste-like and to insure a high integrity joint, the epoxy preferably being cured at 250° F. for 50 minutes minimum.

In greater detail, the end of the straight tube portions **16** of the hairpin tubes **18** terminate in neck portions **30** which taper inwardly, preferably at an angle of approximately 5° and, in turn, the return bend tube **22** is provided with flared portions **32** at each end which

taper outwardly at the same angle and extend axially the same length as the neck portions **30** of the tube ends to be mated therewith. Preferably, in forming both the flared and neck ends of both tubes **18** and **22,** a mechanical deformation or swaging process may be employed with respect to both mating surfaces, to create longitudinal surface indentations or, scratches constituting an axially roughened section which materially increases the wetability between the epoxy **34** which is applied to either the male tapered surface portion **30** or the female tapered portion **32** of tubes **18** and **22** respectively. Alternatively, the epoxy **34** may be applied to both surfaces after degreasing, as mentioned previously.

Coupling of the extreme of the outside tube ends to aluminum tubular couplings **26,** is achieved in an identical manner. In this case, however, the couplings which consist of cast aluminum alloy, include a threaded bore **36** within a flange area **38,** and the tubular fitting **26** is provided with an outwardly flared or tapered counter-bore **40** which is also at an angle of approximately 5° to the tube axis. Thus, the tapered bore **40** acts as the female mating surface for the necked terminal ends **30** of tubes **18.** Again, either mating surface **40** or surface **30** may have applied thereto either a coating of epoxy as at **34** or both surfaces may have applied coatings prior to assembly.

Reference to FIGS. **5** and **6** indicates portions of a completed assembly after curing. It is noted that during the axial insertion of the male mating surfaces **30** into the respective female surfaces **24** of the return bend tube **22** and **40** of the tubular end fittings **26,** the insertion terminates when there is a full wetting of the surfaces by the epoxy which may be visually observed by the extrusion of a thin bead **34'** of epoxy about the edge **42** of the return bend tube **22** and the outer edge **44** of each of the threaded fittings **26.** Once assembled in this manner, curing is achieved at 250° F. for a time period in excess of 50 minutes. The completed assembly may then be tested for leaks and any joints which are found leaking are repaired in a simple manner by applying heat to the zone of the epoxy until it burns which is above approximately 600° F. for the 2214 high temperature structural epoxy adhesive. At this temperature, the aluminum tubing and the aluminum cast fittings **26** are unaffected. The return bend tube **22** and the fittings **26** are removed after the epoxy burns and the charred exposed epoxy is cleaned either mechanically or chemically. After the burned epoxy is removed, the parent metal is exposed and is cleaned, permitting assembly in the manner of FIG. **1** involving normal preparation, that is, degreasing, epoxy application, return bend and fitting assembly and curing. If necessary a chemical remover and a separate cleaner may be used under the trade names Cee Bee and product designations A227D and 21D respectively or equivalents. Epoxy may be cleaned effectively by emersing the coil ends for approximately one hour in the A227D chemical remover.

From the above, it is readily evident in a simplified two-tube heat exchanger coil, a single hairpin tube may be employed with fittings such as fittings **26** at the free ends thereof and coupled by the epoxy jointing techniques set forth above. Further, multi-tube coils may be manufactured without the necessity of the fittings **26** with the ends of the outside tubes being connected directly to piping, hoses or the like carrying oil, liquid or gaseous refrigerant or the like.

From the above description it is readily apparent that an epoxy joint of aluminum tubes or tubular members by the improved method has many advantages. The assembly of the invention allows positive positioning of the parts to be joined in terms of the area which is to be epoxy bonded and at the same time asures the complete wetting of the mating surfaces by the bond material without scraping off any of the epoxy due to the axial movement of the tubular members into position for joining by the epoxy bond. This is to be contrasted to conventional joining of tubes by epoxy bond or otherwise in which either the inside of the female tube or the outside of the male tube is first coated with the bonding material, then, if parallel surfaces carry the coating material during the telescoping of the male member within the female member, there is a tendency for the bonding material to be scraped from the telescoping surfaces. This not only creates voids, inclusions, or pockets devoid of bonding material, but necessitates attempting to rectify such a situation which to date have been ineffective to repair the damage. In one attempt, the application of suction to one of the tubes to cause the bonding material to be pulled in the direction of suction application, still prevents complete circumferential wetting of the mating surfaces and does not materially better the uniformity in thickness of the bonding material. In fact, it has a tendency to move the material axially rather than circumferentially and thus the voids created by axial insertion of one parallel tube surface within another are not eliminated by this approach.

To the contrary, the method assures complete wetting of the mating surfaces by the bond material without any scraping, since axial shifting of the male member with respect to the female is terminated when a small bead of epoxy is exposed at the outer edge of the female member which is indicative of full circumferential wetting along the complete mating tapered surfaces. The reverse tapering of matched mating surfaces insures uniformity in thickness and a good bond without voids, inclusions or pockets. Further, even if there is incomplete cleaning prior to the application of the epoxy and subsequent curing, there is still an excellent chance that a completely sealed joint is formed and the manufactured part will not have to be discarded or reprocessed by burning out the epoxy, recleaning and reapplication and curing of the epoxy.

With the illustrated coil, there is in its most simple form the assembly of a single return bend tube as a fitting which in itself is simple in view of the joint configuration. The male taper of the tube and the female taper of the return bend provide a self-aligning relationship when mated to insure proper position and preventing cocking of one tube with respect to the other. The mating surfaces are presumed to provide a close gap with minor variances. Preferably, the surfaces are roughened purposely during mechanical deformation to provide the flare and the necking and thus assure maximal effectiveness of the bond.

In fact, the total mated surface area provides a lap joint which has a sheer strength in excess of the tube and where the epoxy joint is prepared and cured properly, destructive pull tests indicate that failure occurs not at the joint but at adjacent sections of the tube. The coils of the illustrated type have been employed in cooling lubricating oils circulating through the tubes at 250 psig and 250° F. without problem.

When contrasted to brazed joint copper heat exchanger in terms of the illustrated coil assembly, the economic return employing the method of the present invention is startling. The cost of an equivalent epoxy joint between aluminum tubular members may be as low as 1/10 of those involving a brazed joint between copper tubes and as low as 1/100 of the conventional comparative brazed joint between aluminum tubular members. Further, tests conducted on epoxy joint, aluminum tube heat exchangers of the type illustrated in FIGS. 1 and 2 indicate seal failure of less than one-tenth of 1 percent as contrasted to initial seal failure of as high as 5 percent for the equivalent copper brazed joint copper tube heat exchangers. These coils were tested at said temperature and pressure by imparting vibrations to the coil structure and keeping at the natural frequency for an hour without any apparent weakening or bond leaks.

What is claimed is:

1. In a heat exchange coil of the type including a plurality of adjacently positioned first hairpin shaped aluminum tubes carrying internally, a high pressure fluid, and being commonly supported by a plurality of longitudinally spaced heat exchange fins with the straight portions of said tubes extending through holes within the fins and with the ends of two separate tubes being joined by a second, U-shaped return bend aluminum tube, the improvement wherein: the ends of one of said tubes are flared and the ends of said other tubes are necked to define axially opposed tapered mating surfaces, and wherein said tubes are coupled together solely by a uniform thickness epoxy adhesive between said mating surfaces to complete a high integrity, fluid seal bond therebetween of sufficient strength to prevent longitudinal separation of the return bend tube from the straight portions of the tubes joined thereto due to the high fluid pressure acting directly on said return bend tube and creating a resultant force tending to longitudinally separate the return bend tube from said hairpin tubes.

2. The heat exchange coil as claimed in claim **1,** wherein said first tubes are two in number and are coupled together by a second return bend tube and wherein said heat exchange coil further includes threaded aluminum tubular fittings having complementary tapered mating surfaces epoxy bonded to the outside ends of said respective first tubes in identical fashion to that of said return bend tube and acting as the sole means for coupling said fittings to said said first tubes.

3. The heat exchange coil assembly as claimed in claim **1,** wherein said first tubes terminate in male neck portions defining inwardly tapered mating surfaces and said second return bend tube terminates in flared portions defining corresponding outwardly tapering mating surfaces and said assembly further includes threaded tubular aluminum fittings coupled to the outside ends of respective first tubes, said threaded tubular aluminum fittings each including an axially tapered bore which mates with a necked end of said first tube with a uniform thickness epoxy adhesive bonding the mating surfaces therebetween, and acts as the sole means for coupling said fittings to the outside ends of respective first tubes.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,877,518

DATED : April 15, 1975

INVENTOR(S) : Moshe Y. Dreksler

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

The term of this patent subsequent to August 13, 1991,

has been disclaimed.

Signed and Sealed this

Twenty-fourth Day of August 1976

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,877,518 Dated April 15, 1975

Inventor(s) Moshe Y. Dreksler

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

On the first page, after the name of the inventor, please insert the name of the assignee:

--- Dunham-Bush, Inc.

West Hartford, Conn. ------

Signed and sealed this 24th day of June 1975.

(SEAL)
Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents
and Trademarks

FORM PO-1050 (10-69)

USCOMM-DC 60376-P69
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