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(54) **CONCENTRIC TUBE HEAT EXCHANGER END SEAL THEREFOR**

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(57) **ABSTRACT**

A concentric tube heat exchanger comprises an outer tube and a concentric inner tube, with an annular passageway between the tubes. The ends of the annular passageway are sealed by sealing members having axially extending inner and outer walls which are connected to one another and which are sealed to the respective outer and inner tubes. The sealing member walls are preferably connected by an integrally formed connecting wall. The walls of the sealing member are preferably resilient and diverge so as to form a friction fit with the tubes during assembly of the heat exchanger. The heat exchanger further comprises a turbulizer which comprises a plurality of rows of corrugations defining axially extending flow passages. Preferably, the corrugations have a top land width greater than a bottom land width so that the side walls of the corrugation are radially arranged in the annular passageway. Adjacent corrugations in each row are preferably offset relative to one another by an amount of from about 30 percent to about 40 percent.

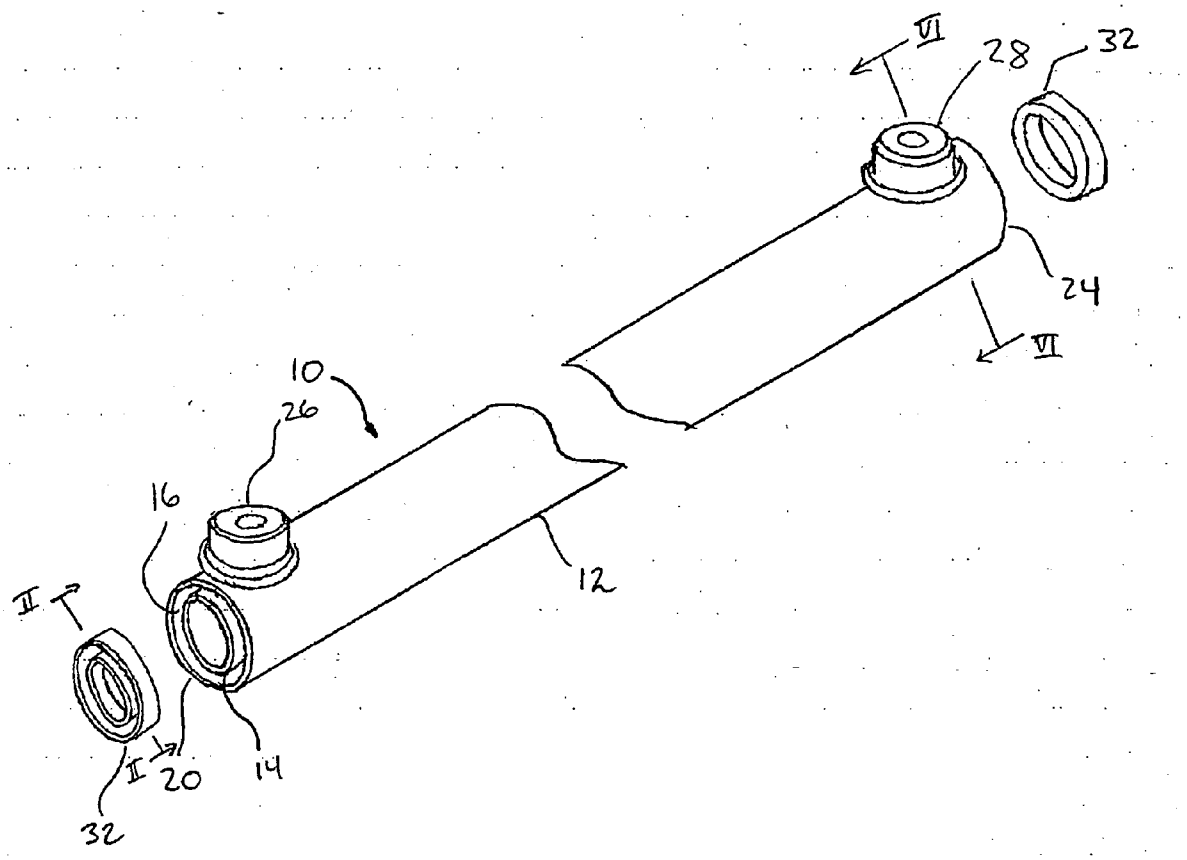


FIG. 1

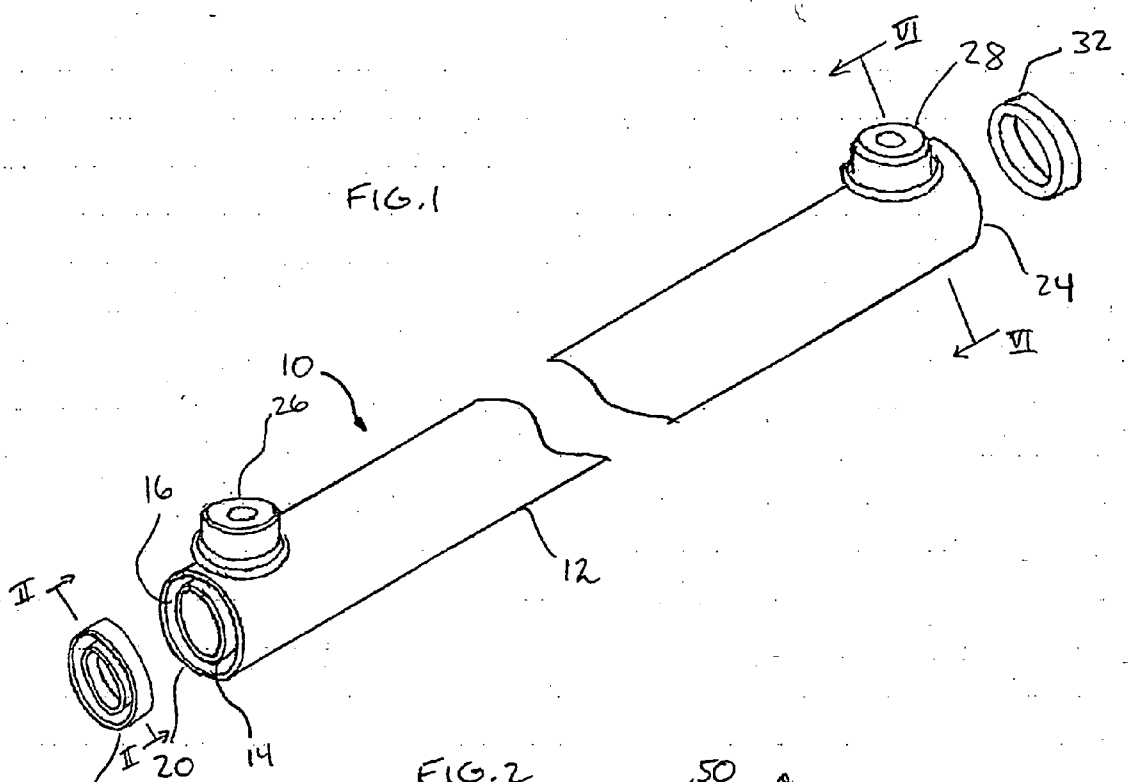


FIG. 2

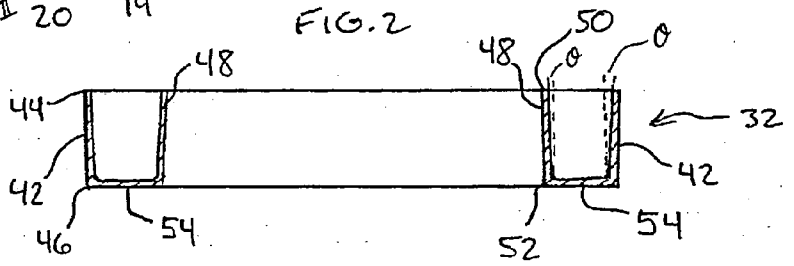
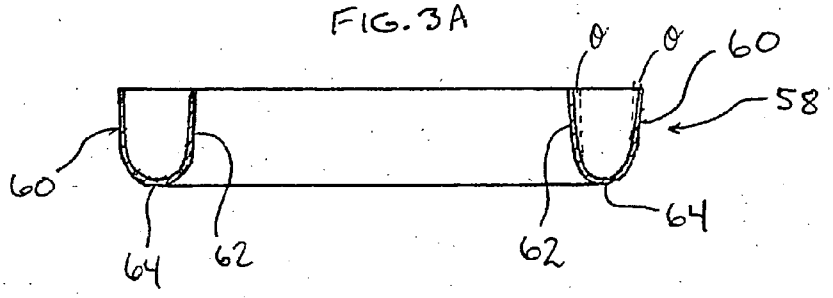


FIG. 3A



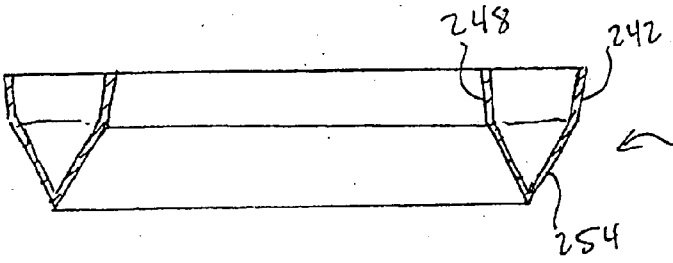


FIG. 3C

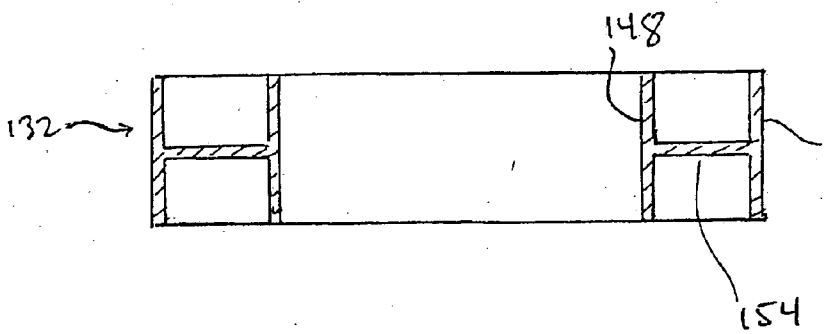


FIG. 3B

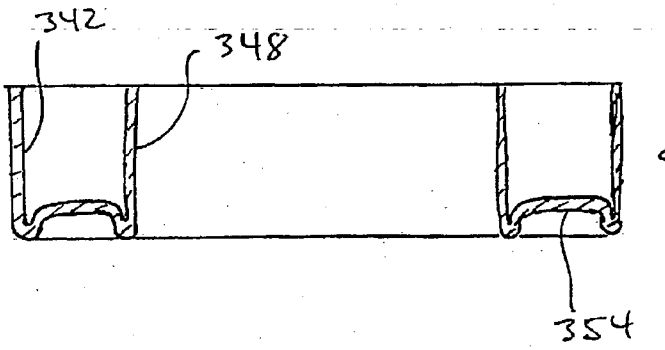


FIG. 3D

FIG. 4

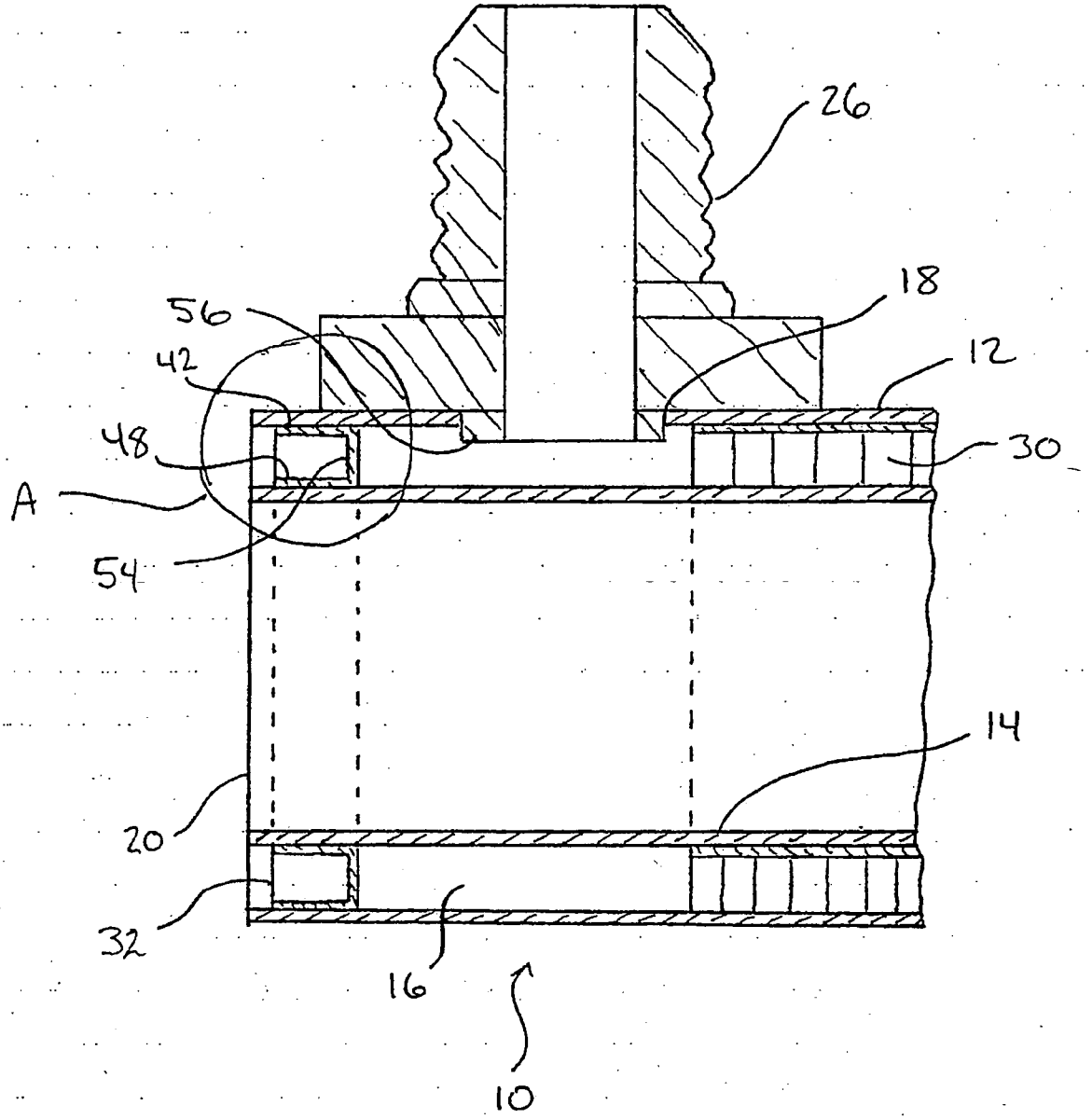


FIG. 5

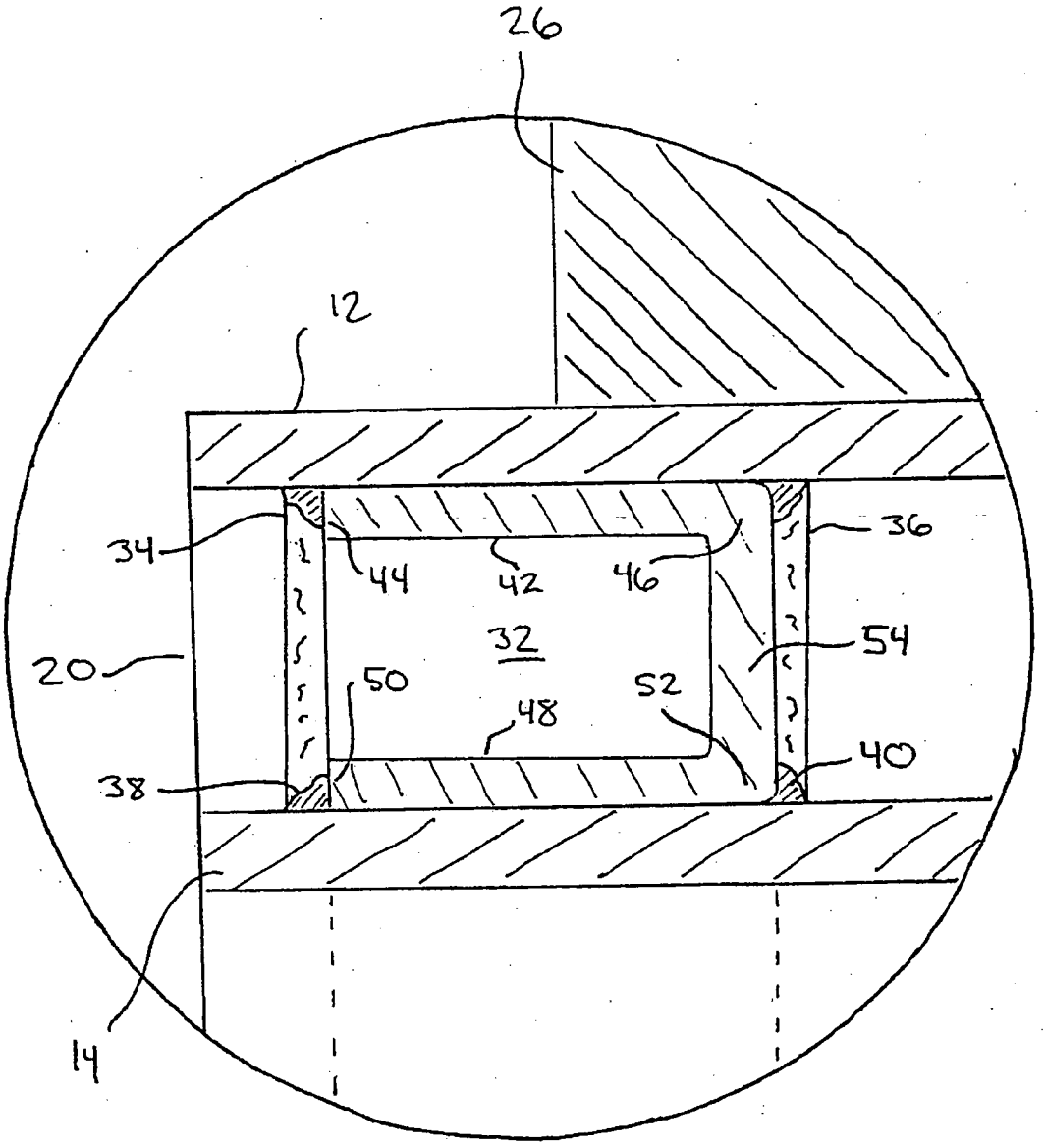
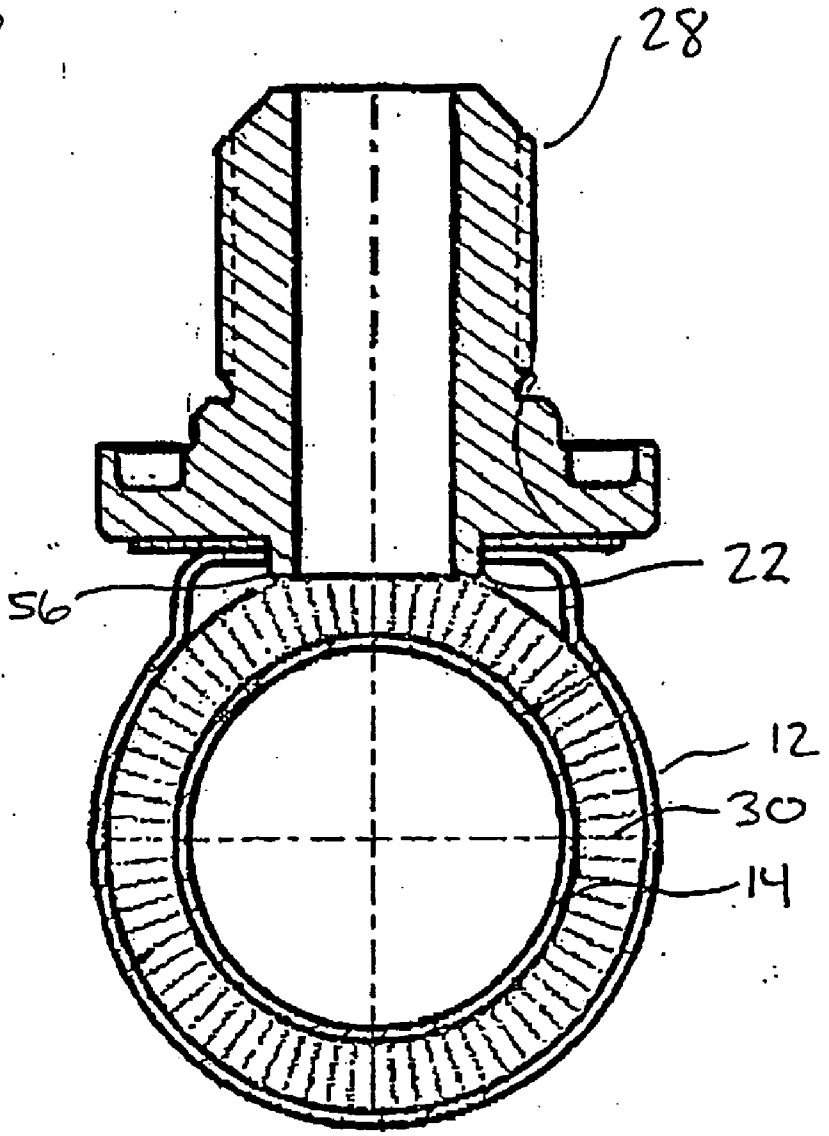


FIG:6



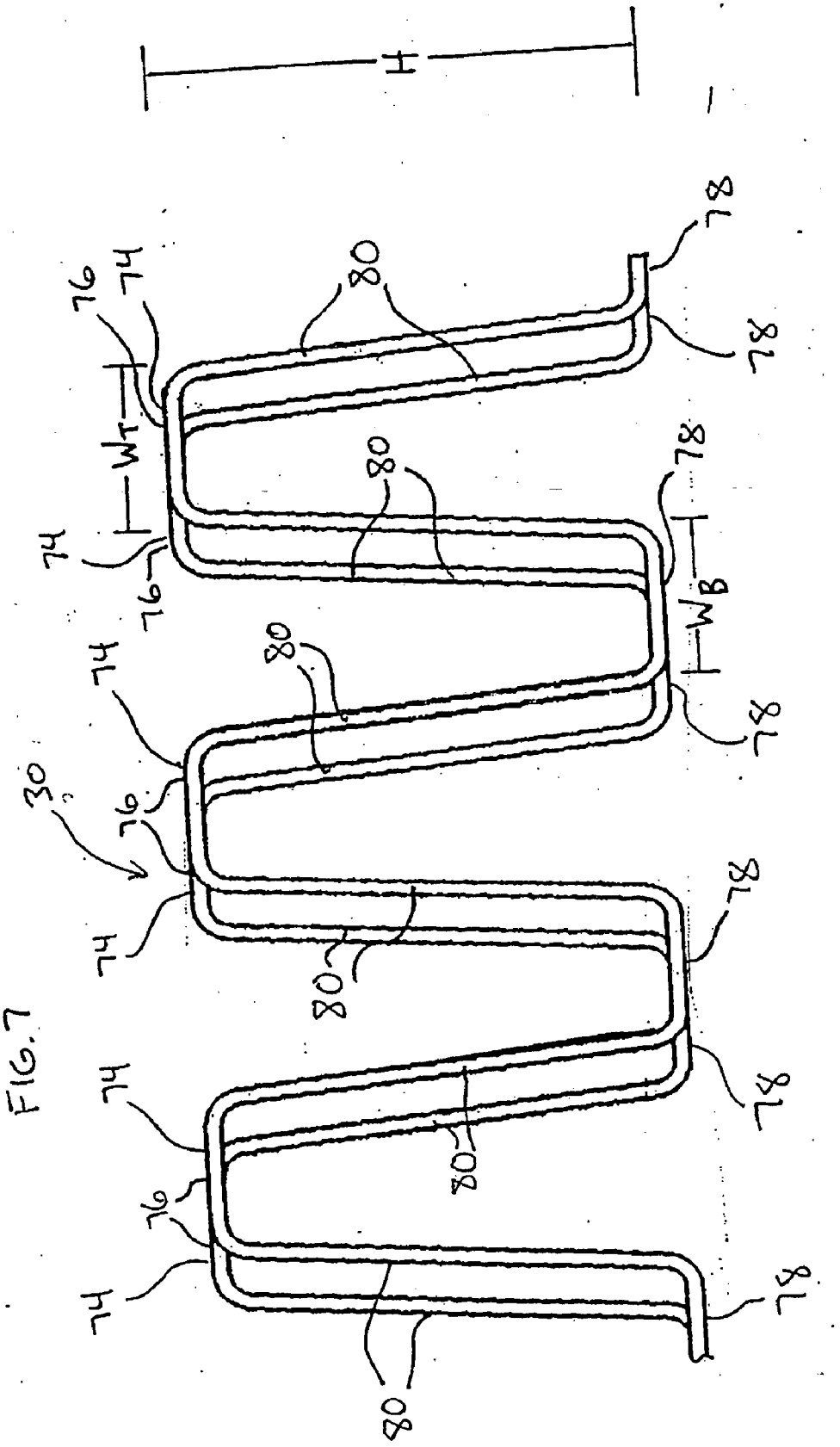
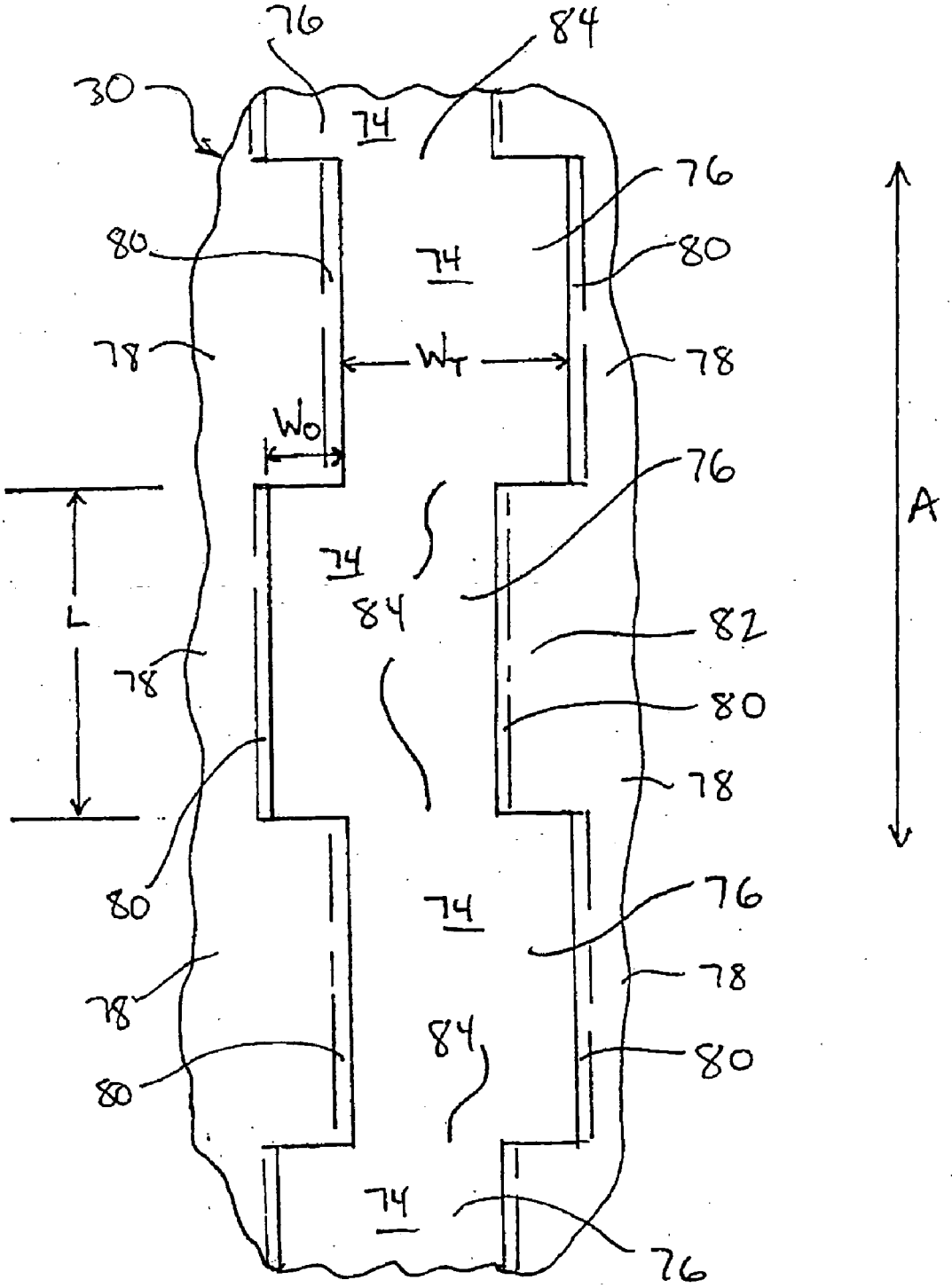


FIG. 7

FIG. 8


76
84
30
74
76
80
74
80
78
W_T
78
W_O
76
A
74
L
84
82
78
80
78
80
74
76
78
78
84
80
80
74
76

CONCENTRIC TUBE HEAT EXCHANGER END SEAL THEREFOR

FIELD OF THE INVENTION

[0001] This invention relates to concentric tube heat exchangers, and more particularly to seals for closing an annular passageway between the inner and outer tubes of such heat exchangers.

BACKGROUND OF THE INVENTION

[0002] Concentric tube heat exchangers are commonly employed as transmission and transaxle oil coolers and are mounted in the coolant tank or manifold of a vehicle radiator. These heat exchangers include a cylindrical outer tube, a cylindrical inner tube and a turbulizer placed in an annular passageway between the inner and outer tubes. Oil is admitted to the annular passageway via an inlet port located at one end of the tube for passage through the turbulizer. The oil is cooled and exits via an outlet port located near the other end of the outer tube.

[0003] Numerous arrangements are known in the prior art for sealing the ends of the annular passageway. These include deformation of the inner and/or outer tubes, for example as shown in U.S. Pat. No. 3,001,767 (Straubing), U.S. Pat. No. 5,732,769 (Staffa) and U.S. Pat. No. 5,950,716 (Appelquist et al.); or by use of annular seals as described in U.S. Pat. Nos. 3,323,586 and 3,339,260 (Burne et al.)

[0004] The suitability of prior art end sealing methods can be affected by the type of material from which the heat exchanger is made. For example, in aluminum concentric tube heat exchangers, it has proven difficult to seal the annular passageway by deformation of the tubes. This has led some manufacturers to seal the annular passageway with machined aluminum end blocks, which significantly increase the weight and cost of the heat exchanger.

[0005] Accordingly, there is a need for improved methods for sealing the annular passageway in a concentric tube heat exchanger which will provide economical and reliable sealing in a variety of materials.

SUMMARY OF THE INVENTION

[0006] In one aspect, the present invention provides a concentric tube heat exchanger having a first end and a second end. The heat exchanger comprises an outer tube and an inner tube. The inner tube is received inside the outer tube and concentric therewith, wherein an annular passageway is formed between the inner and outer tubes. The heat exchanger further comprises first and second annular sealing members received inside the annular passageway between the inner and outer tubes. The first sealing member is positioned proximate the first end of the heat exchanger and the second sealing member is positioned proximate the second end of the heat exchanger. Each of the sealing members comprises an outer wall and an inner wall which are connected to one another, each of the walls having first and second axially-spaced ends, the outer wall being sealed to the outer tube and the inner wall being sealed to the inner tube, thereby sealing the ends of the tubes.

[0007] The concentric tube heat exchanger according to the invention further comprises a turbulizer received in the annular passageway between the tubes. The turbulizer comprises a plurality of corrugations defining a plurality of axially extending flow passages extending parallel to the tubes. Each of the corrugations comprises a top land, a bottom land and a pair of side surfaces connecting the top and bottom lands, the top land being in heat exchange contact with the outer tube and the bottom land being in heat exchange contact with the inner tube. The convolutions are arranged in axially extending rows with the convolutions in each row being connected to one another and with an offset being provided between adjacent convolutions in each row. The offset has a width which is from about 30 percent to about 40 percent of a width of the top land or the bottom land.

[0008] In another aspect, the present invention provides a sealing member for sealing opposite ends of an annular passageway extending along an axis between inner and outer tubes of a concentric tube heat exchanger. The sealing member comprises an outer wall and an inner wall. The outer wall has first and second axially-spaced ends and a generally axially-extending portion between its ends for sealing to the outer tube. The inner wall has first and second axially-spaced ends, is connected to the outer wall and is spaced radially inwardly of the outer wall. The inner wall has a generally axially-extending portion between its ends for sealing to the inner tube. The generally axially-extending portions of the walls diverge from one another along said axis.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

[0010] **FIG. 1** is a perspective view of a preferred heat exchanger according to the invention, prior to insertion of the sealing members;

[0011] **FIG. 2** is a cross section through one of the sealing members along line II-II in **FIG. 1**;

[0012] **FIGS. 3A** to **3**D are cross sections through alternate preferred sealing members according to the invention;

[0013] **FIG. 4** is a cross section in an axial plane through one end of the heat exchanger of **FIG. 1**, after insertion of the sealing members;

[0014] **FIG. 5** is a close-up of area A in **FIG. 4**;

[0015] **FIG. 6** is a cross-section along line VI-VI of **FIG. 1**;

[0016] **FIG. 7** is a front view of a portion of a turbulizer sheet according to the invention; and

[0017] **FIG. 8** is a top plan view of a portion of the turbulizer sheet of **FIG. 7**.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0018] **FIG. 1** illustrates a preferred concentric tube heat exchanger **10** according to the invention. Heat exchanger **10** comprises an outer cylindrical tube **12** and an inner cylindrical tube **14**, the inner tube **14** being received in the outer tube **12** and concentric therewith, with an annular passage-

way **16** being formed between the outer and inner tubes **12**, **14** and extending through substantially the entire length of the heat exchanger **10**.

[**0019**] Heat exchanger **10** further comprises an inlet port **18** located adjacent its first end **20** and an outlet port **22** (**FIG. 6**) located adjacent its second end **24**. Both the inlet and outlet ports **18**, **22** comprise perforations formed in the outer tube **12** through which a fluid to be cooled, such as oil, is allowed to enter and exit the annular passageway **16**. The heat exchanger **10** further comprises an inlet filting **26** and an outlet filting **28** which are mounted to the outer surface of the outer tube **12** in communication with the inlet and outlet ports **18**, **22** respectively. To assist in mounting and sealing the filtings **26**, **28** to outer tube **12**, the areas surrounding inlet and outlet ports **18**, **22** are preferably flattened, as shown in **FIG. 6**. Sealed connections are formed between filtings **26**, **28** and the outer surface of tube **12**, for example by brazing.

[**0020**] Not shown in **FIG. 1**, but described in detail below, is a turbulizer **30** which is received in the annular passageway **16** and extends through the annular passageway **16** between the inlet and outlet ports **18**, **22**.

[**0021**] Lastly, the heat exchanger **10** comprises a pair of annular sealing members **32** for sealing the ends of the annular passageway **16**. In **FIG. 1**, the heat exchanger **10** is shown in a partially disassembled state with the sealing members **32** separated from the tubes **12**, **14**. **FIG. 4** illustrates the first end of heat exchanger **10** in its assembled state with a sealing member **32** received in the annular passageway **16** and brazed to both the outer and inner tubes **12**, **14**.

[**0022**] As shown in **FIG. 4**, sealing member **32** is received inside the annular passageway **16** between the outer and inner tubes **12**, **14**. The sealing member **32** is located proximate the first end **20** of heat exchanger **10** and, more particularly, is located between the inlet port **18** and the first end **20** of the heat exchanger **10**. The sealing member **32** is sealingly connected to both the inner surface of the outer tube **12** and the outer surface of the inner tube **14**, preferably by brazing, with braze fillets **34** and **36** being formed between the sealing member **32** and the outer tube **12**, and braze fillets **38** and **40** being formed between the sealing member **32** and the inner tube **14**. The braze fillets **34**, **36**, **38** and **40** are shown only in the close-up of **FIG. 5**. It will be appreciated that the second end **24** of heat exchanger **10** is preferably sealed in an identical manner with the other sealing member **32** illustrated in **FIG. 1**.

[**0023**] The preferred sealing members **32** shown in the drawings each comprise an outer wall **42** and an inner wall **48**, with the inner wall **48** being spaced radially inwardly of the outer wall **42**, and preferably concentric therewith. The outer wall **42** has a first end **46** and a second end **44**, the ends **44**, **46** being axially spaced from one another, with at least a portion of the outer wall extending generally along the axis. Similarly, the inner wall has a first end **52** and a second end **50**, the ends **50**, **52** being axially spaced from one another, with at least a portion of the outer wall extending generally along the axis. In the sealing members **32** shown in the drawings, the entire outer and inner walls **42** and **46** extend along the axis, with the inner wall **48** abutting the outer surface of inner tube **14** and sealed thereto, and with the outer wall **42** abutting the inner surface of outer tube **12** and sealed thereto. However, it will be appreciated that this is not necessary that the entire outer and inner walls **42**, **48** extend generally axially. Rather, it will be appreciated that only portions of walls **42**, **46** are required to extend axially, sufficient to form seals with the outer and inner tubes **12**, **14**, respectively.

[**0024**] The sealing members **32** illustrated in the drawings are of generally U-shaped cross section, with the first end **46** of the outer wall **42** being connected to the first end **52** of the inner wall **48** by a radially extending connecting portion **54** which seals the radial space between the walls **42**, **48**. The second ends **44**, **50** of the walls **42**, **48** are distal to the connecting portion. Preferably, the connecting portion **54** is integrally formed with the walls **42**, **48**.

[**0025**] As shown in **FIG. 2**, the outer and inner walls **42**, **48** of the sealing member are not necessarily parallel to one another. Rather it is preferred that the walls **42**, **48**, or the generally axially extending portions thereof, diverge from one another along the axis. Preferably, the walls **42**, **48** diverge from one another from the connecting portion **54** toward the second ends **44**, **50** such that a radial distance measured between the walls **42**, **48** at the connecting portion **54** is less than a radial distance measured between the second ends **44**, **50** of walls **42**, **48**. Furthermore, the material from which the walls **42**, **48** are formed is preferably sufficiently resilient such that, when the sealing members **32** are inserted into the annular passageway with the connecting portions **54** spaced inwardly of the ends **20**, **24** by a greater distance than the second ends **44**, **50** of walls **42**, **48** (as shown in **FIG. 4**), the second ends **44**, **50** become compressed so that the sealing member walls **42**, **48** frictionally engage the respective tubes **12**, **14**, thereby retaining the sealing members **32** during the assembly process. The angle at which the walls **42**, **48** diverge is sufficient for easy insertion of the sealing members **32** into the annular passageway **16** with a friction fit, while ensuring substantially complete contact between the walls **42**, **48** and the tubes **12**, **14** after the inner tube is expanded during the manufacturing process, thus ensuring leak-proof braze joints. The inventors have found that these objects can be achieved by forming sealing members with at least one, and preferably both, side walls **42**, **48** diverging from the axis by an angle θ of from about 1 to about 2 degrees, more preferably about 1.5 degrees.

[**0026**] As shown in **FIG. 4**, the sealing member **32** is preferably spaced inwardly from the end **20** of the heat exchanger **10**, for at least two reasons. Firstly, it will be noted from **FIG. 4** that the turbulizer **30** does not extend past the inlet port **18** and, in fact, is prevented from doing so by a collar **56** of inlet fitting **26**, the collar **56** projecting into the annular passageway **16** through the inlet port **18** and acting as a stop for the turbulizer **30**. Thus, the turbulizer **30** does not provide support for the portion of annular passageway **16** extending from the inlet port **18** to the first end **20** of the heat exchanger **10**. To minimize the unsupported area of annular passageway **16** and thereby avoid narrowing of the annular passageway **16** in the area surrounding inlet port **18**, the sealing member **32** is located inwardly of the end **20** of heat exchanger **10**, between the inlet port **18** and the end **20**. Secondly, locating the sealing member inward of the end **20** ensures that there is sufficient area for formation of braze fillets **34** between the top **44** of outer wall **42** and the inner surface of outer tube **12**, and between the top **50** of inner

tube **14** and the outer surface of inner tube **14**. The formation of continuous braze fillets about the entire circumference of each sealing member ensures robust, leak proof joints at the ends **20**, **24** of the heat exchanger.

[**0027**] As shown in **FIG. 2**, the connecting portion **54** of the sealing member is preferably flat and extends radially between the outer and inner walls **42**, **48** of the sealing member **32**. **FIG. 3A** illustrates an alternate preferred form of sealing member **58** having outer and inner walls **60**, **62** diverging from the axis by an angle θ and connected at their bottoms by a rounded connecting portion **64**. It will also be appreciated that numerous alternate constructions of sealing members are possible without departing from the present invention. For example, as shown in **FIG. 3B**, a sealing member **132** may be of generally H-shaped cross section, with the connecting member **154** extending radially between the sealing member walls **142**, **148** intermediate the first ends **146**, **152** and the second ends **144**, **150**. Alternatively, **FIG. 3C** shows a sealing member **232** which is of generally V-shaped cross section, and in which a V-shaped connecting member **254** extends between sealing member walls **242**, **248**, which extend generally axially. **FIG. 3D** shows a sealing member **332** which is of modified U-shaped construction, having a somewhat indented connecting portion **354** extending between the outer and inner walls **342**, **348**.

[**0028**] In a particularly preferred embodiment of the present invention, all the components of heat exchanger **10** are formed from aluminum or alloys thereof, and are preferably formed from brazeable aluminum alloys. In particular, the tubes **12**, **14** are preferably of welded and drawn construction and comprise an aluminum alloy core layer clad on at least one side with an aluminum brazing alloy. More preferably, the inner surface of the outer tube **12** and the outer surface of the inner tube **14**, i.e. the "oil-side" surfaces, are clad with a brazing alloy, while the opposite surfaces of these tubes, i.e. the "water-side" surfaces, are clad with an alloy containing an amount of zinc for sacrificial corrosion protection. Where the oil-side surfaces of tubes **12**, **14** are clad with a brazing alloy, it will be appreciated that neither the turbulizer **30** nor the sealing members **32** require a cladding of brazing alloy. It will be appreciated that alternate arrangements are possible, for example, the turbulizer **30** and sealing members **32** may be clad with brazing alloy, and the tubes **12**, **14** may be unclad. Alternatively, all these components may be clad with a brazing alloy. In yet another alternative, the heat exchanger **10** may be comprised of non-clad aluminum members, and the filler metal for brazing may be provided by means of a brazing paste or preform, and brazing can be accomplished by either flux or fluxless brazing by suitable selection of the braze system and materials. Similarly, a brazing paste or preform can be used to join the fittings **26**, **28** to the corrosion resistant clad water-side surface of the outer tube **12**.

[**0029**] It will be appreciated that the sealing members **32** may be installed with the second ends **44**, **50** of walls **42**, **48** facing the inlet or outlet port **18**, **22**. However, for manufacturing purposes, it is preferred that the sealing members **32** are received in the annular passageway with the second ends **44**, **50** of walls **42**, **48** facing the ends **20**, **24** of heat exchanger **10**, as shown in the drawings.

[**0030**] The heat exchanger **10** is preferably by assembled by inserting the inner tube **14** and the turbulizer **30** into the outer tube **12**, inserting the sealing members **32** into the opposite ends **20** and **22**, expanding the inner tube so that both the outer and inner tubes **12**, **14** are in intimate heat exchange contact with the turbulizer **30**, applying the fittings to the outer tube, and then brazing the assembly in a brazing oven.

[**0031**] A preferred form of turbulizer **30** is now described below with reference to **FIGS. 7 and 8**. Turbulizer **30** is of generally the same construction as the turbulizer described in U.S. Pat. No. Re. 35,890 (So), which is incorporated herein by reference in its entirety. In particular, prior to insertion into the annular passageway **16**, the turbulizer **30** is in the form of a sheet having a plurality of convolutions **74** which define a plurality of flow passages. The flow passages extend axially (parallel to arrow A in **FIG. 8**) once the turbulizer **30** is rolled up and inserted into the annular passageway **16**. Each of the convolutions **74** has a height H (**FIG. 7**), a length L (**FIG. 8**), a rectangular top land **76** having width W_T (**FIGS. 7 and 8**), a rectangular bottom land **78** having a width W_B, and a pair of side surfaces **80** extending between the top and bottom lands **76**, **78**. In a particularly preferred embodiment of the present invention, the convolutions **74** have a height of about 3 mm and a length of at least about 1.6 mm. It will be appreciated that all width dimensions described herein are measured perpendicular to the axial direction.

[**0032**] The top lands **76** of the convolutions **74** are arranged in axially extending rows, as seen in **FIG. 8**, which shows a single row **82** of convolutions **74**. The top lands **76** of the convolutions **74** in each row **82** are connected to one another along their front and rear edges at areas **84** (**FIG. 8**) and are offset relative to one another, with the width of the offset being W_O (**FIG. 8**). It will be appreciated that a bottom plan view of the turbulizer **30** has an appearance which is substantially the same as that shown in **FIG. 8**.

[**0033**] The features of turbulizer **30** described above are also present in the turbulizer described in the above-mentioned So patent. The turbulizer **30** according to the invention differs from the So turbulizer in several important respects, which are now discussed below.

[**0034**] Firstly, the turbulizer **30** according to the invention has a preferred offset W_O which is significantly less than that of the So turbulizer, thereby maximizing the width of the area **84** along which the convolutions **84** are connected with one another. In the So turbulizer, the width of offset is about 50 percent of the width of the top and bottom lands, whereas the offset in the turbulizer **30** according to the invention is about 30 to 40 percent (i.e. W_O/W_T or W_B=0.30-0.40), preferably about 31 to about 36 percent. The inventors have found that decreasing the offset of the convolutions **74** helps to ensure formability of the turbulizer **30** from metals such as aluminum, while providing high heat transfer and low pressure drop.

[**0035**] Secondly, the turbulizer **30** according to the invention is formed with the top land width W_T which is greater than the bottom land with W_B, and with the side surfaces **80** of each convolution **74** sloping away from one another from the top land **76** to the bottom land **78**. Thus, when the turbulizer sheet **30** is rolled up and inserted into the annular passageway **16** with the bottom lands **78** in heat exchange contact with the inner tube **14** and the top lands **76** in heat exchange contact with the outer tube **12**, the side surfaces **80**

are extend substantially radially between the outer tube **12** and inner tube **14**, producing axial flow passages of substantially constant cross-sectional area. This helps to maximize heat transfer and minimize pressure drop.

[**0036**] In a particularly preferred embodiment of the invention, the side surfaces are sloped at about 5° from vertical, the top land width W_T is about 1.1 mm, the bottom land width W_B is about 1.0 mm, the centers of rows **82** are spaced about 2.1 mm apart, and the offset with W_O is about 0.35 mm. In a turbulizer having these dimensions, the offset expressed as a percentage of the top land width is about 31 percent and the offset expressed as a percentage of the bottom land width is about 36 percent.

[**0037**] The above-mentioned features of the turbulizer according to the invention, for example the top and bottom lands of different width, the radially extending side surfaces, and the decreased offset, ensure optimum fit-up of the turbulizer during assembly, thereby maximizing metal-to-metal contact between the turbulizer and the tubes, which ensures brazeability and optimum heat transfer.

[**0038**] Although the invention has been described in connection with certain preferred embodiments, it is not intended to be limited thereto. Rather, the invention includes all embodiments which may fall within the scope of the following claims.

1-17. (canceled)

18. A sealing member for sealing an annular gap between inner and outer axially-extending tubes of a concentric tube heat exchanger, the sealing member comprising:

an outer wall having first and second axially-spaced ends and having a generally axially-extending portion between its ends for sealing to the outer tube; and

an inner wall having first and second axially-spaced ends, the inner wall being connected to the outer wall and being spaced radially inwardly of the outer wall, the inner wall having a generally axially-extending portion between its ends for sealing to the inner tube;

wherein the generally axially-extending portions of the walls diverge from one another along said axis.

19. The sealing member of claim 18, wherein the inner and outer walls are connected through a connecting portion, the second ends of the sealing member walls are axially spaced from the connecting portion which seals a radial space between the sealing member walls.

20. The sealing member of claim 18, wherein the generally axially-extending portions of the walls are resilient, and wherein the generally axially-extending portions diverge from one another at an angle such that, when the sealing member is received in the annular gap with the outer wall frictionally engaging the outer tube and the inner wall frictionally engaging the inner tube, and such that the generally axially-extending portions of the sealing member walls are in substantial engagement with the inner and outer tubes.

21. The sealing member of claim 18, wherein the generally axially-extending portion of at least one of the sealing member walls diverges from the axis by an angle of from about 1 to about 2 degrees.

22. The sealing member of claim 18, wherein the generally axially-extending portions of the inner and outer sealing member walls diverge from the axis by an angle of from about 1 to about 2 degrees.

23. The sealing member of claim 21, wherein said angle is about 1.5 degrees.

24. The sealing member of claim 22, wherein said angle is about 1.5 degrees.

25. The sealing member of claim 19, wherein the sealing member is generally U-shaped, with the first ends of the sealing member walls being connected to the connecting portion and the second ends of the sealing member walls being distal to the connecting portion.

26. The sealing member of claim 25, wherein the connecting portion is rounded.

27. The sealing member of claim 25, wherein the connecting portion is flat and extends radially between the inner and outer walls.

28. The sealing member of claim 25, wherein the connecting portion is V-shaped.

29. The sealing member of claim 25, wherein the connecting portion is indented toward the second end of the outer wall.

30. The sealing member of claim 19, wherein the connecting portion is attached to the sealing member walls between the first and second ends, such that the sealing member is generally H-shaped.

31. The sealing member of claim 19, wherein the connecting portion is integrally formed with the sealing member walls.

32. The sealing member of claim 18, wherein the walls are formed from a material which is sufficiently resilient such that the second ends of the first and second walls are compressible toward one another.

33. The sealing member of claim 32, wherein the walls are comprised of aluminum.

34. A method of manufacturing a concentric tube heat exchanger comprising inner and outer axially-extending tubes and an axially-extending annular passageway between the tubes, the method comprising:

(a) providing a pair of annular sealing members, each of the sealing members comprising a resilient outer wall having a first end and a second end, a resilient inner wall having a first and a second end and being spaced from the outer wall, and a connecting portion through which the inner and outer walls are connected;

(b) inserting the sealing members into opposite ends of the annular passageway such that at least a portion of the inner wall and at least a portion of the outer wall of the sealing members are generally axially aligned, wherein the inner and outer walls are compressed toward one another during insertion of the sealing members into the annular passageway, such that the generally axially-aligned portions of the inner and outer walls frictionally engage the inner and outer tubes, respectively; and

(c) expanding the inner tube such that the generally axially-extending portions of the inner and outer walls of the sealing member are parallel to one another and are in substantially complete contact with the inner and outer tubes, respectively.

35. The method of claim 34, wherein the tubes and the sealing members are comprised of aluminum and wherein the method further comprises:

(d) brazing the generally axially-extending portions of the sealing member walls to the inner and outer tubes.

36. The method of claim 35, wherein the tubes and/or the sealing members are provided with a cladding comprised of a brazing alloy, at least on surfaces at which the sealing members and the tubes are brazed together.

37. The method of claim 34, wherein the annular passageway has open ends through which the sealing members are inserted, and wherein the sealing members are inserted inwardly of the ends of the annular passageway.

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