

[54] **TUBULAR HEAT EXCHANGER SUPPORTING AND SPACER STRUCTURE**

1,017,455 1/1966 Great Britain.....165/162  
 1,188,564 4/1970 Great Britain.....165/162  
 685,283 4/1964 Canada .....165/162

[75] Inventors: Kurt Fritz, Klosterneuburg; Josef M. Lippitsch, Graz, both of Austria; Gunther Lurf, Stuttgart, Germany

Primary Examiner—William F. O'Dea  
 Assistant Examiner—William C. Anderson  
 Attorney—Steinberg & Blake

[73] Assignee: Waagner-Biro Aktiengesellschaft, Vienna, Austria

[22] Filed: Sept. 22, 1970

[21] Appl. No.: 74,356

[30] **Foreign Application Priority Data**

Sept. 26, 1969 Austria .....A 9160/69

[52] U.S. Cl. ....165/162, 165/163

[51] Int. Cl. ....F28f 9/00

[58] Field of Search .....165/67, 69, 162, 163

[56] **References Cited**

**UNITED STATES PATENTS**

3,199,582 8/1965 Vogt et al. ....165/69  
 3,352,289 11/1967 Cunningham, Jr. et al. ...122/250 R X  
 3,554,168 1/1971 Woebcke .....122/510  
 3,439,737 4/1969 Boorman et al. ....165/162 X

**FOREIGN PATENTS OR APPLICATIONS**

685,848 1/1953 Great Britain.....165/162

[57] **ABSTRACT**

Heat exchangers having spirally wound tubes for accommodating in their interior an inner heat-exchanging fluid while being engaged at their exterior by an outer heat-exchanging fluid. The spirally wound tubes are arranged one next to the other surrounding a given axis with the convolutions of one tube axially aligned with the convolutions of the next tube. The tubes form a group having an inner region directed toward the latter axis and an outer region directed away from the latter axis. At one of these regions there is a supporting structure while a spacer structure is fixed to the supporting structure and extends between the convolutions of the tubes to form with the latter a unitary assembly of tubes acting as a unitary structure in which the convolutions are maintained at given locations with respect to each other. The spacer structure serves to transmit to the supporting structure the weight of the tubes and the spacer structure as well as any thermal or mechanical stresses or reaction forces resulting from flow of the fluids during operation of the heat exchanger.

12 Claims, 8 Drawing Figures

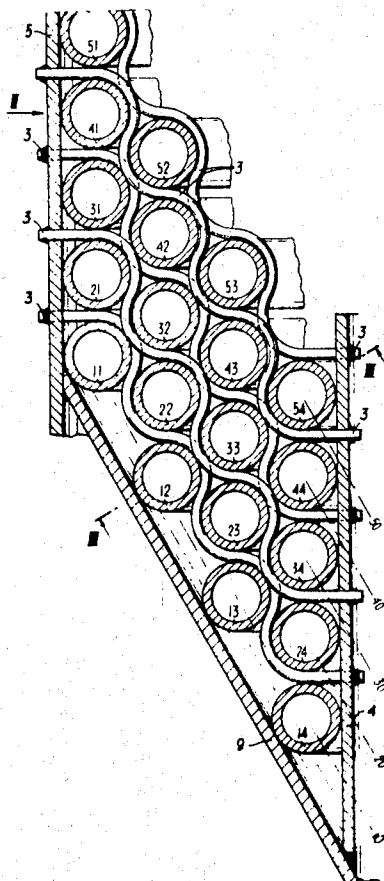


FIG. 1

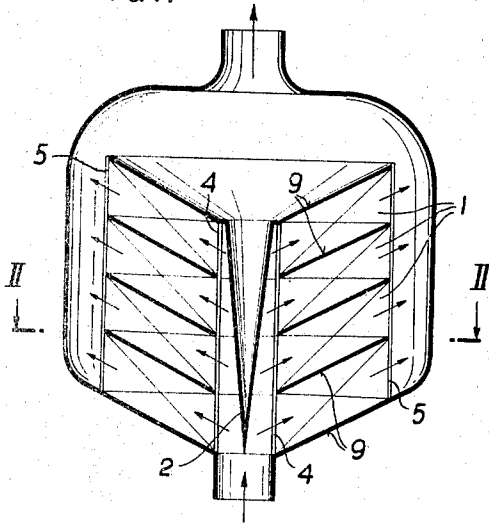


FIG. 2

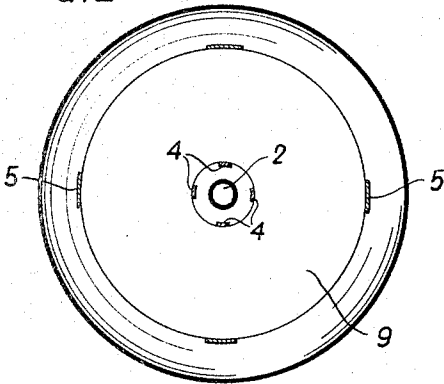


FIG. 8

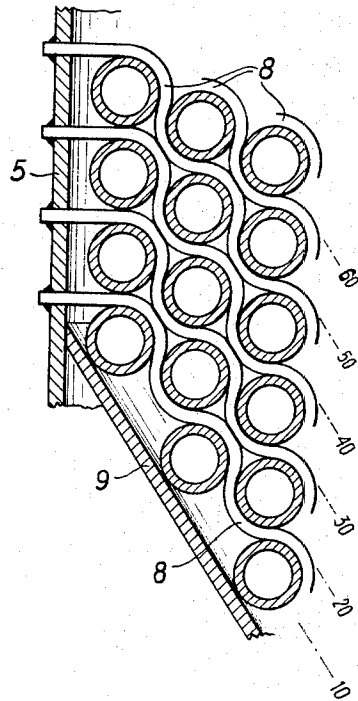


FIG. 6

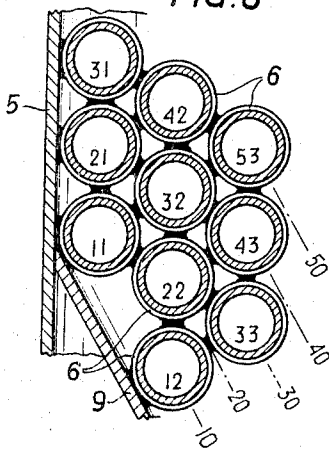
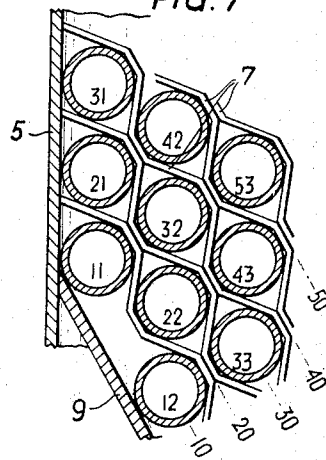
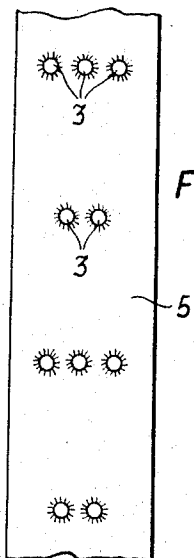
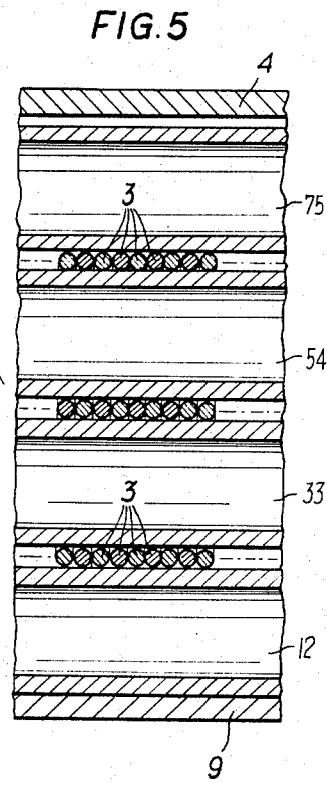
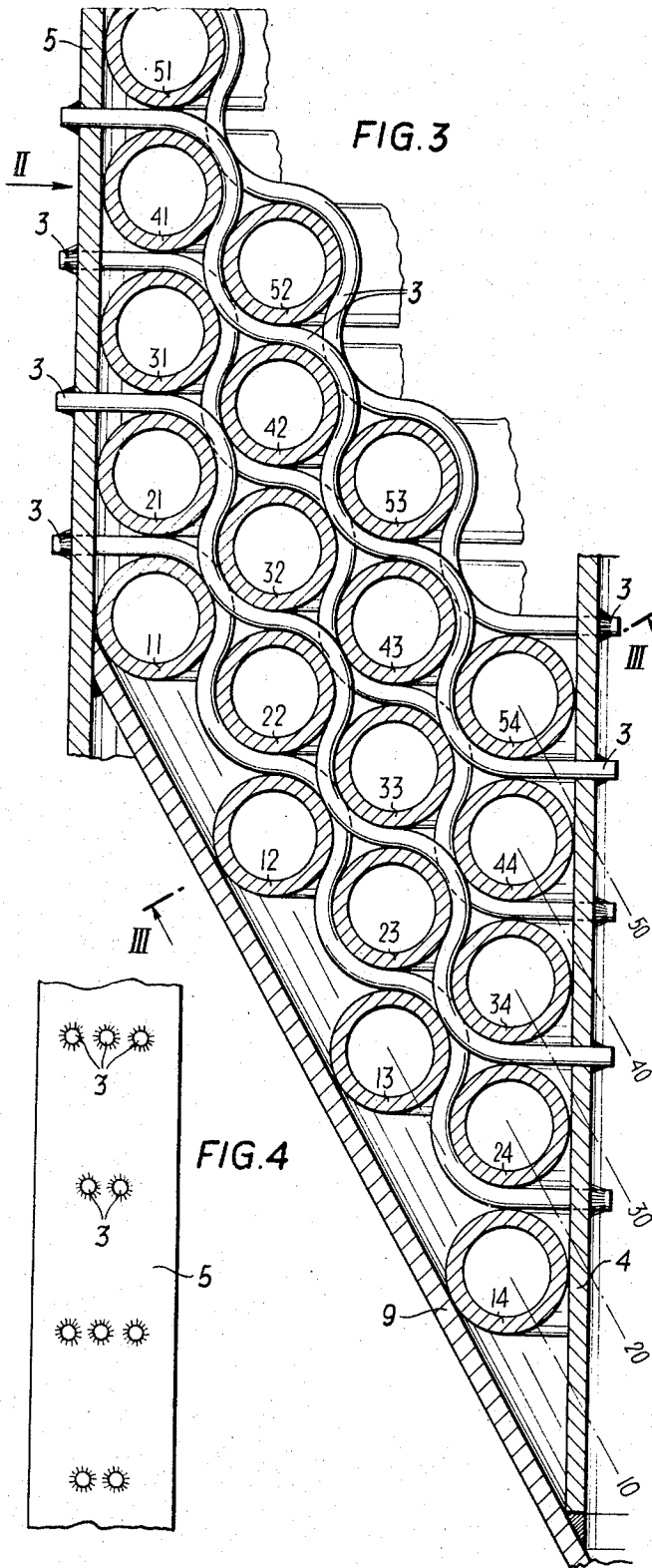


FIG. 7





## TUBULAR HEAT EXCHANGER SUPPORTING AND SPACER STRUCTURE

### BACKGROUND OF THE INVENTION

The present invention relates to heat exchangers.

In particular, the present invention relates to heat exchangers composed of spirally wound tubes with spacers situated therebetween to provide between the tubes flow paths for an outer heat exchanging fluid which engages the exterior of the tubes the interior of which accommodates an inner heat-exchanging fluid.

Although structures of this general type are known, the conventional structures suffer from several drawbacks. Thus, the tubes of conventional structures are subjected to extremely great stresses resulting very often in failures which require shutting down of the operation of the heat exchanger. Thus, expansion and contraction of the tubes due to the influence of the temperature and thermal changes will often result in failures. In addition, during operations, as a result of the weight of the structure itself as well as reaction forces from the flow of the fluids vibrations are induced which also result in failures with the conventional constructions. Furthermore, with conventional heat exchangers it is difficult to work with a heat exchanging fluid which is at extremely high pressure while at the same time providing pressure vessels which are relatively small in size and inexpensive. It is not possible with conventional constructions to achieve a large heat-exchanging area in a relatively small volume.

### SUMMARY OF THE INVENTION

It is accordingly a primary object of the present invention to provide a heat exchanger which will avoid the above drawbacks.

In particular, it is an object of the present invention to provide a tubular heat exchanger where all of the stresses encountered by the tubes are reliably and effectively transmitted to a rugged supporting structure so that the tubes themselves are not subject to failure from stresses encountered during operation.

Furthermore, it is an object of the present invention to provide a construction of this type which results in any assembly of tubes which can respond elastically to thermal stresses and which also can respond to any vibratory forces in a manner transmitting the stresses effectively to a rugged supporting structure without subjecting the tubes to failure.

In addition, it is an object of the present invention to provide an exceedingly compact assembly of tubes capable of handling fluids at high pressure while at the same time providing an extremely large heat-exchanging area for each unit of volume at the interior of the heat exchanger so that within a relatively small vessel it is possible to accommodate high-pressure fluids with an effective heat-exchange assured.

In accordance with the invention, the heat exchanger includes a plurality of spirally wound tubes for accommodating in their interior an inner heat-exchanging fluid while an outer heat-exchanging fluid is adapted to engage the exterior of tubes. The spirally wound tubes are arranged one next to the other with the convolutions of one tube axially aligned with the convolutions of the next tube, and the several tubes form at least one group of tubes having an inner region surrounding a given axis, and directed toward this axis, while the

group of tubes has an outer region directed away from this axis. A support means is situated adjacent at least one of these regions of the tubes, and a spacer means extends between the convolutions of the tubes for maintaining the convolutions at a given spacing with respect to each other. This spacer means forms a unitary structural assembly with the tubes and is operatively connected with the support means to transmit to the latter forces resulting from the weight of the tubes and the spacer means as well as any mechanical or thermal stresses or forces resulting from reactions to the flow of the fluids, so that in this way substantially all stresses encountered during operation are transmitted to the support means.

### BRIEF DESCRIPTION OF DRAWINGS

The invention is illustrated by way of example in the accompanying drawings which form part of this application and in which:

FIG. 1 is a schematic representation of a heat exchanger provided with the structure of the invention;

FIG. 2 is a schematic plan view of the heat exchanger taken along line I—I of FIG. 1 in the direction of the arrows;

FIG. 3 is a fragmentary axial sectional elevation showing the details of one embodiment of a structure of the invention;

FIG. 4 shows the structure of FIG. 3 as viewed in the direction of arrow II of FIG. 3, illustrating the manner in which a spacer means and support means are interconnected;

FIG. 5 is a fragmentary sectional illustration taken along line III of FIG. 3 in the direction of the arrow and showing further details of the embodiment of FIG. 3;

FIG. 6 is a fragmentary axial section illustrating another embodiment of the structure of the invention;

FIG. 7 is a fragmentary axial section illustrating a further embodiment of a heat exchanger of the invention; and

FIG. 8 is a fragmentary axial section illustrating a still further embodiment of a heat exchanger according to the invention.

### DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to FIG. 1, there is schematically represented therein, in an axial section which contains the central axis of the illustrated heat exchanger, a plurality of groups 1 of heat-exchanging tubes where each group has the tapered configuration illustrated. Groups of tubes are situated one above the other surrounding the central axis of the heat exchanger with these groups of tubes having an inner region directed toward the central axis and an outer region directed away from the central axis. The exterior heat-exchanging fluid flows through the heat exchanger in the manner indicated by the arrows in FIG. 1 so that the outer heat exchanging fluid has at the groups of tubes 1 the main direction indicated by the arrows which extend upwardly toward the baffles 9 which separate the several groups 1 from each other. These baffles are simply in the form of tapered annular walls each forming part of a cone whose center is in the central axis of the heat exchanger. Along the central axis of the heat exchanger there is a conical baffle 2 which has its apex directed downwardly and situ-

ated substantially at the receiving end of the heat exchanger where the exterior heat-exchanging fluid is received. This conical baffle 2 will direct the outer fluid between the baffles 9 and along the exteriors of the tubes which form the several groups 1.

A support means is provided for supporting the tubes which form the groups 1, and this support means includes outer elongated bodies 5 extending parallel to the axis of the heat exchanger and situated at the outer region of the groups 1. The support means also includes inner elongated bodies 4 which extend parallel to the axis of the heat exchanger and which are situated at the inner region of the groups of tubes 1. As is apparent from FIG. 2, these inner bodies 4 and outer bodies 5 are in the form of elongated bars extending parallel to the axis of the heat exchanger and fixed in any suitable way to the outer wall of the heat exchanger, such as to the bottom tapered wall thereof illustrated in FIG. 1. The several tapered baffles 9 are also fixed to and extend between the bars 4 and 5 which form the elongated bodies of the support means. Thus, the annular baffles 9 may be welded at their outer edges to the inner surfaces of the axial bars 5 of the support means and at their inner edges to the outer surfaces of the axial inner bars 4 of the support means. As is apparent from FIG. 2, the several bars 5 as well as the several bars 4 are circumferentially distributed about the central axis of the heat exchanger with these bars being arranged in radially aligned pairs. Thus, in the illustrated example there are four elongated bars 5 extending parallel to the heat exchanger axis and distributed thereabout through equal angles, these four bars 5 being respectively radially aligned with the four inner bars 4. The welding of these bars 4 and 5 to the tapered baffles 9 forms a supporting framework for the several groups of tubes.

Referring now to FIG 3, a pair of radially aligned bars 4 and 5 of the support means are illustrated therein in an axial section with the lower baffle 9 which is welded to these bars also being illustrated. FIG. 3 illustrates five spirally wound tubes of a group, these tubes 10, 20, 30, 40 and 50 being arranged with the convolutions of one tube axially aligned with the convolutions of the next tube. Thus, in the illustrated scheme the lowermost tube 10 has convolutions 11, 12, 13, 14 from the outer to the inner region of the spirally wound tube, the next tube 20 has the convolutions 21-24 respectively axially aligned with the convolutions 11-14, and so on. This scheme of designating the several spirally wound tubes and their convolutions is followed also in FIGS. 6-8.

In the embodiment of FIGS. 3-5 there is a spacer means 3 in the form of metal wires which are curved so as to have a wave-shaped configuration. These wires are welded at their ends to the radially aligned bars 4 and 5 of the support means. The several wires 3 which form the spacer means extend over and under the convolutions of the tubes in the manner illustrated in FIG. 3 so as to interconnect the tubes with each other while maintaining them at a given spacing with respect to each other. Following any one of the wires 3 of FIG. 3 from the bar 5 toward the bar 4 it will be seen that each wire 3 extends first over and under adjoining convolutions of one tube, then over and under adjoining convolutions of the next tube and so on, so that each of the

wires 3 serves not only to maintain a given spacing between adjoining convolutions of the same tube but also to maintain the spacing between adjoining convolutions of adjoining tubes. In the illustrated example where wires are used to form the spacer means of the invention, it is of advantage to arrange a plurality of wires beside each other somewhat along the lines illustrated in FIG. 4. As is apparent from FIG. 4 the wires at one elevation are situated in alignment with the spaces between the wires at the next elevation, with this lateral spacing between the wires being substantially equal to the diameters of the wires. As a result the wires which extend over a convolution of one tube into engagement with the next axially aligned convolution of the next tube will become situated between the wires which extend over this latter tube. Thus, as may be seen from FIG. 5 which is taken in a plane normal to the main direction of flow of the outer fluid, the several wires 3 will become situated one next to the other between the tubes, thus forming wire bands which provide the spacers determining the spacing between the several tubes. Of course in FIG. 5 there are more wires than appears from FIG. 4 which has been simplified for the sake of clarity. Thus, the inner and outer bars 4 and 5 form the elongated bodies of the support means which together with the tapered baffles 9 of the support means form the supporting structure for the bundles of tubes. The several wires 3 extend through suitable bores in the bars 4 and 5 and are welded to the exterior surfaces thereof which are directed away from the tubes, as is apparent from FIGS. 3 and 4.

In connection with FIG. 5, it is to be understood that the section line extends from the center of the tube 54 parallel to the bar 4 so that FIG. 5 shows the next tube at its inner convolution 64 which is axially aligned with the convolution 54 of the tube 50 and which directly engages the next higher baffle 9 as illustrated in FIG. 5. Thus, the group of six tubes in the illustrated example is situated between the baffles 9 which are fragmentarily illustrated in FIG. 5.

In the embodiment of FIG. 6 there are shown five tubes 10, 20, 30, 40, 50 of a group with these tubes fragmentarily illustrated sectionally in an axial plane. In this embodiment the spacer means takes the form of annular bodies 6 in the forms of rings or sleeves which surround and engage the tubes and which are welded to each other at those locations where they engage each other so that in this way also the spacer means of this embodiment will form a network of the tubes providing the equivalent of a unitary structure.

In the embodiment of FIG. 7, the spacer means 7 takes the form of angled strips of sheet metal, which while being substantially wave-shaped and following substantially the paths occupied by the wires 3 of FIG. 3, are in fact relatively sharply angled narrow strips of sheet metal which are welded to each other where they engage each other so as to form a honeycomb type of spacer means as illustrated in FIG. 7. Of course in the case of FIG. 7 as well as FIG. 6 the parts of the spacer means which engage the bars 4 and 5 of the support means are welded thereto. Thus, those rings 6 which engage the bars 4 and 5 are directly welded thereto. In FIG. 7 the ends of the strips 7 are welded to the bars 4 and 5.

In the embodiment of FIG. 8 the spacer means also takes the form of elongated relatively narrow strips of sheet metal, but these strips are curved so as to form to the configurations of the wires 3 while at the same time having a width corresponding to the spacers 7 of FIG. 7. The curvature of the wave-shaped spacer strips 8 is such that in this embodiment each strip extends around the axis of a convolution through approximately 120°, and of course the same is true of the wires of FIG. 3. In this case also the several strips 8 are welded at their ends to the bars 4 and 5 in the manner illustrated for the bar 5 in FIG. 8.

In each of the embodiments of the invention the tubes are spirally curved in such a way that they will have with respect to each other the relationship shown, for example, in FIG. 3, although this relationship is also illustrated in FIGS. 6-8. Thus, in an axial plane which contains the axis of the heat exchanger, the several tubes will have at their convolutions cross sections the centers of which are situated as illustrated in FIG. 3. This arrangement is such that the centers of any group of three adjoining convolutions of a pair of tubes will form either an isosocles triangle or an equilateral triangle. For example, the center of convolution 22 of FIG. 3 forms with the centers of convolutions 32 and 43 of the next pair of successive tubes, in an upward direction as viewed in FIG. 3, and equilateral triangle in the axial plane of FIG. 3. Any similar group of three convolutions of three successive tubes will have the same relationship. On the other hand, the center of the convolution 32 forms with the centers 21 and 22 of the next adjoining tube an isosocles triangle. In the same way the center of convolution 11 forms with the centers of convolutions 21 and 22 also an isosocles triangle. Thus, the centers of three adjoining convolutions of three successive tubes will form an equilateral triangle in an axial plane while a pair of adjoining convolutions of one tube with the intermediate convolution of the next tube will form an isosocles triangle in an axial plane. Furthermore, at each tube any one convolution has a diameter only slightly greater than the outer diameter of the next inner convolution, so that between the convolutions of the several tubes there are formed narrow, spiral paths through which the exterior heat-exchanging fluid is adapted to flow, achieving in this way an extremely favorable heat exchange. In the embodiment of FIGS. 3 and 8, the distribution of the tubes in an axial direction is such that in this axial direction the spacing between the tubes is equal to the diameters of a pair of successive axially aligned convolutions plus a single thickness of a spacer component. In a direction which is normal to the main direction of flow of the exterior fluid, which is to say in a plane containing the axes of convolutions 12, 33, and 54 in FIG. 3, the distribution of the tubes also is equal to the diameters of a pair of successive convolutions plus a single thickness of the spacer component, while in the embodiment of FIG. 8 the distribution in this direction is equal to that of a pair of successive convolutions plus twice the thickness of the spacer members. As was pointed out above the spacer members of FIGS. 3 and 8 extend through 120° around the exterior of each convolution.

In all embodiments the spacers bring about a uniform distribution of the tube convolutions under all operating conditions and they also serve to transmit the load

to the support means formed by the bars 4 and 5. It is preferred to weld the spacers to each other where they engage each other, as pointed out above.

The above-described structure of the invention provides a number of advantages, among which are the following:

Each group of tubes is thermally elastic. Only very small additional stresses are encountered in the tubes as a result of the influence of temperature and thermal changes.

The spacer means of the invention acts as a faultless vibration node with a known damping action which remains constant during operation of the heat exchanger, since the weight of the tubes themselves and any other forces acting thereon, such as, for example, the forces of the flowing fluids, will bring about a predetermined and constant pressing force.

The convolutions of the tubes are narrowly wound. An extremely large heating surface is provided for each unit of volume. Thus, an extremely large heat-exchange area is provided for each unit of volume. This advantage is of particular importance when the heat-exchanging fluid is a fluid medium which is at high pressure, since the pressure vessel in this case can be maintained small and therefore can have a low cost. Also, with this construction it is possible to achieve a high heat transfer or heat-exchanging coefficient. With the embodiment of FIG. 3 as well as that of FIG. 8, the exterior fluid is required to flow through narrow gaps equal to the thickness of only a single spacer component, thus providing an extremely compact assembly with a high coefficient of heat transfer with these particular embodiments.

In all of the embodiments the spacer means formed by the spacer components forms with the tubes a single unitary structural assembly acting as one unit in response to the stresses which are encountered, with substantially all of the load and stresses being transmitted to the rugged support means formed by the bars 4 and 5. In effect the spacers of the invention serve to hang or suspend the tubes of the convolutions from the bars 4 and 5. Thus, while the lowermost tube of any group may be considered as supported by the lower baffle 9, as illustrated in FIG. 3 for the tube 10, the next higher tube is supported by the lowermost spacer, and it will be seen that the several tubes 20-50 of FIG. 3 are in fact supported by the spacer means so as to be suspended thereby between bars 4 and 5, and of course the same is true for the embodiments of FIGS. 6-8.

Moreover, it will be seen that with all embodiments of the invention the tubes are arranged so close to each other that extremely narrow gaps are defined therebetween compelling the exterior fluid to flow at a high speed so as to achieve an extremely efficient rate of heat exchange, enabling the area of heat exchanging surfaces to be reduced so as to achieve for a heat exchanger of a given size an output greater than has heretofore been possible. Referring to FIGS. 3 and 6-8, it will be seen that the convolutions of the several tubes are axially aligned one above the other and the axial gap between any pair of axially aligned convolutions of a pair of adjoining tubes is substantially less than the radius of any tube. In addition, it will be seen that the gap between any tube convolution and the next adjoining outer or inner convolution is also substantially less

than the radius of any tube. These extremely narrow gaps between the convolutions are achieved with the spacer means of the invention, and it is these extremely narrow gaps which enable all the convolutions to be crowded together to such an extent that extremely narrow paths of flow are provided at the exterior surfaces of the tubes to achieve the above results.

What is claimed is:

1. In a heat exchanger, at least one group of spirally wound tubes for accommodating in their interior an inner heat-exchanging fluid while an outer heat-exchanging fluid engages the exterior of said tubes, said tubes surrounding a predetermined axis and being arranged adjacent each other with the convolutions of each tube substantially in axial alignment with the convolutions of the next tube, and said tubes having an inner region directed toward said axis and an outer region directed away from said axis, support means situated adjacent one of the latter regions of said tubes, and spacer means engaging said tubes and connected to said support means for interconnecting said tubes and forming therefrom a unitary assembly where said tubes remain in a predetermined relation with respect to each other determined by said spacer means and for transmitting to said support means forces resulting from the weight of said tubes and spacer means as well as any other forces which result from mechanical or thermal stresses or reaction forces resulting from the flow of the heat-exchanging fluids, said spacer means coating with said tubes for providing narrow gaps therebetween with the axial gap between any pair of adjoining axially aligned convolutions of a pair of tubes being substantially less than the radius of any tube while the gap between any tube convolution and the next inner and outer convolution also is substantially less than the radius of any tube, said spirally wound tubes having convolutions axially displaced and extending along a spiral forming part of a cone whose apex is at said axis, a pair of tapered baffles also forming parts of cones and coaxially surrounding said axis with said tubes being situated between and engaging said baffles so that the latter directs the outer fluid across the exterior of said tubes, additional groups of spirally wound tubes being arranged next to and engaging said baffles at sides thereof which are respectively directed away from said one group, and said baffles being made of sheet material and having a total thickness equal to the thickness of said sheet material so that successive groups of tubes are separated from each other only by a distance equal to the thickness of said sheet material, said support means including elongated supporting bodies spaced from and extending parallel to said axis at the inner and outer regions of said tubes with said bodies being spaced from each other and distributed about said axis at each of said regions and the bodies of said support means at said outer region being radially aligned with the bodies of said support means at said inner region so that said support means includes a plurality of pairs of radially aligned bodies, and said spacer means including elongated thin spacer components which are at least partially of wave-shaped configuration such components being fixed to the pairs of radially aligned

bodies of said support means and extending therebetween over and under the convolutions of said tubes, and said baffles having outer edges fixed to said bodies of said support means which are at said outer region and inner edges which are fixed to said bodies of said support means which are at said inner region, and said groups of tubes being carried exclusively by said spacer means and baffles between said bodies of said support means which are respectively situated at said outer and inner regions.

2. The combination of claim 1 and wherein said spacer means includes elongated strips of angularly bent sheet metal welded together and forming a honeycomb spacer structure, said strips being free of any projections and directly engaging said tubes.

3. The combination of claim 1 and wherein said spacer means includes spacer wires groups of which are situated next to each other to form spacer bands.

4. The combination of claim 1 and wherein in an axial plane which contains said axis said tubes have cross sections arranged with the centers of the cross sections of any one tube each forming with a pair of centers of the cross sections of a pair of adjoining convolutions of the next adjoining tubes the corners of an equilateral triangle situated in said axial plane.

5. The combination of claim 4 and wherein each of said tubes has convolutions each of which is only slightly greater than the next inner convolution of each tube so that between the convolutions of the tubes there are formed narrow spiral paths for the outer fluid which engages the exterior of the tubes.

6. The combination of claim 1 and wherein said spacer means includes elongated strips of sheet metal of wave-shaped configuration.

7. The combination of claim 6 and wherein in a direction parallel to said axis the distribution of the convolutions of said tubes is equal to the diameters of tube convolutions which are axially aligned plus a single thickness of said strips between each pair of adjoining axially aligned convolutions of a pair of tubes, said outer fluid flowing in a given main direction across the exteriors of said tubes and said convolutions being distributed in a direction normal to said main direction with a spacing equalling the diameters of said tubes plus twice the thickness of said strips between each pair of adjoining convolutions of said tubes in said direction normal to said main direction.

8. The combination of claim 1 and wherein said spacer means includes annular bodies surrounding and engaging said tubes and fixed to each other.

9. The combination of claim 8 and wherein said bodies are welded to each other.

10. The combination of claim 1 and wherein said spacer components extend over and under the adjoining convolutions of one tube, then over and under the convolutions of the next-adjointing tube, and so on.

11. The combination of claim 10 and wherein said spacer components have ends welded to said radially aligned bodies of said support means.

12. The combination of claim 11 and wherein said bodies of said support means are in the form of elongated bars.

\* \* \* \* \*