April 2, 1963 C. P. ANDERSEN ETAL 3,083,447

METHOD OF ASSEMBLING A BUNDLE OF COILS IN A HEAT EXCHANGE DEVICE

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Fig. 1.

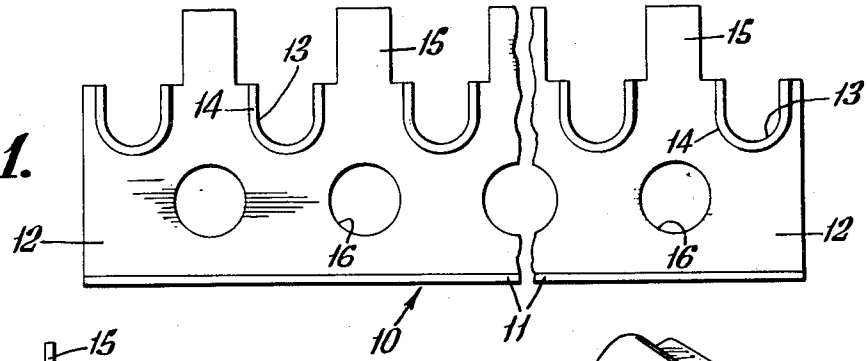


Fig. 2.

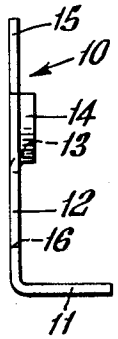


Fig. 3.

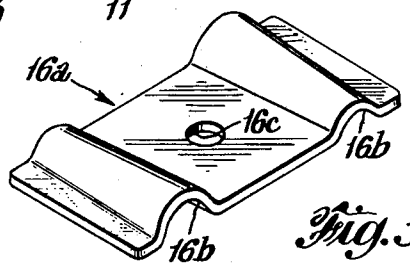


Fig. 5.

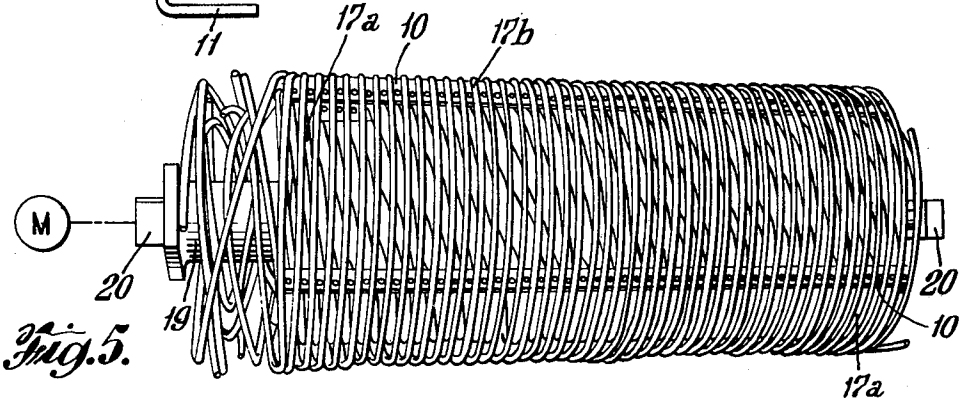
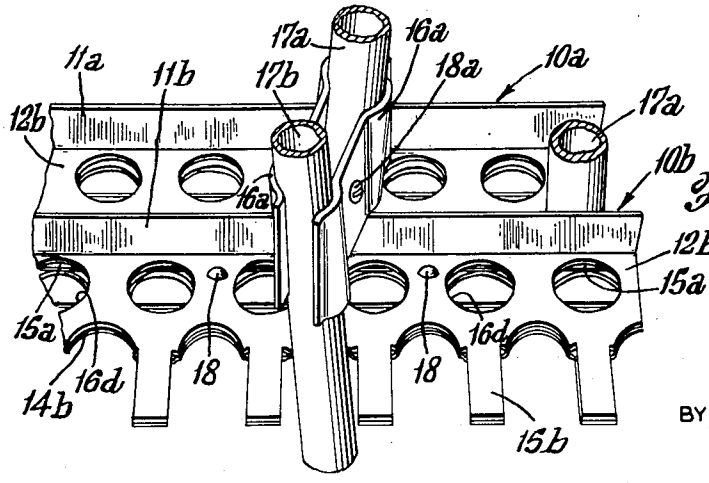


Fig. 4.



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METHOD OF ASSEMBLING A BUNDLE OF COILS IN A HEAT EXCHANGE DEVICE

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Original application Nov. 7, 1957, Ser. No. 695,154, now Patent No. 2,980,404, dated Apr. 18, 1961. Divided and this application Aug. 12, 1960, Ser. No. 50,819

5 Claims. (Cl. 29—157.3)

This invention relates to method of assembling a bundle of coils in heat exchange devices, and more particularly in a shell-coil type heat exchanger in which the coils are wound in substantially uniformly spaced concentric layers within the shell.

This application is a division of our copending application Serial No. 695,154, filed November 7, 1957, for Heat Exchange Device, now Patent No. 2,980,404.

One disadvantage of the heretofore known shell-coil type heat exchangers is the difficulty and expense of assembly; that is, economically forming a large number of closely spaced concentric coils into a compact, well integrated bundle which can be handled and placed in a shell without danger of damage or falling apart. The problem is magnified if the heat exchangers are embedded-coil regenerators for cooling compressed air prior to separation into air components by low-temperature rectification. The coils are embedded in the regenerator packing to provide a means of recovering the refrigeration of an air component as a product gas without contaminating such product with air impurities such as moisture and carbon dioxide. The complexity of the coil assembly problem is illustrated by embedded coil regenerators designed for an air separation plant in which high-purity oxygen product gas is passed through such coils. Such construction may require several miles of tubing wound in perhaps 25 concentric layers. Conceivably the number of separate passages for oxygen flow may exceed 100 tubes, all manifolded together at both ends.

Additional requirements for embedded coil regenerators include low pressure drop through the coils to minimize power costs, and low longitudinal heat leak between the ends of the coils. The latter is necessary because the regenerators must be operated with a large temperature difference between the warm end and the cold end, and longitudinal heat leak represents a loss of refrigeration and results in added power costs. Consequently, the number and size of the longitudinal support members for the concentric coil bundle should be minimized. Still another requirement of regenerator coil bundles is that the individual coils be uniformly spaced from each other so that the fluid passing through the coils is substantially equally warmed by heat transfer from the regenerator packing through the coil walls. The coils should also be closely positioned to each other so as to minimize radial temperature gradients in the packing.

A further unique characteristic of embedded coil regenerators is that all of the coils should preferably contain about the same length of tubing so as to equalize the pressure drop and to obtain uniform flow distribution through the coils. Since the diameters of the coil layers vary from the center to the outside of the bundle, it is clear that the pitch of the windings must also vary, and means must be provided for controlling the tube length and coil pitch during winding as well as maintaining the desired pitch of the various coil layers after they are formed. In the case of large bundles, where the diameter of the inner and outer layers varies considerably, the difference in curvature of the layers may also

have a pronounced effect on pressure drop. This may necessitate a slight variation in tube length between the inner and outer coils so as to equalize flow. In such instances, means must be provided which conveniently permit the selection and installation of the optimum length of tubing in each coil.

One object of the present invention is to provide a highly efficient embedded coil regenerator which is relatively easy and economical to assemble.

Another object of the present invention is to provide an economical method of assembling a bundle of coils in substantially uniformly spaced concentric layers.

A further object is to provide a support system for a bundle of coils in concentric layers whereby the support members regulate the coil pitch during the winding operation, and also maintain the desired pitch of the various coil layers after they are formed.

A still further object of the invention is to provide a support system for a bundle of coils in concentric layers in which the longitudinal heat leak is minimized.

These and other objects and advantages of this invention will be apparent from the following description and accompanying drawings.

In one embodiment of the present invention, a shell-coil type heat exchanger is provided with concentric layers of coils positioned by coil support means comprising a series of support members extending longitudinally between the coil layers for maintaining the coil layers in suitably spaced relation. Slots are provided in each member for receiving and supporting the individual windings of a given layer. A projection between each pair of adjacent slots extends beyond the given layer and provides means for mounting a support member for the next larger diameter coil layer. Also, means such as rivets are provided for securing the next larger diameter coil support member to the projections. The support members for the next larger diameter coil layer may close the slots of the support members of the given coil layer, thereby firmly retaining the coils within the slots.

The individual coil support means are preferably angle-shaped, with two such angles placed back-to-back as a support member for a given coil layer. It is furthermore desirable to form the base of the slots into saddles which receive and distribute the bearing load of the individual coil windings.

In the preferred embodiment, adjacent concentric coil layers are helically wound in opposite directions, i.e., one layer is wound clockwise and the next counterclockwise. Such an arrangement improves flow distribution outside of the coils, and permits equalizing of the stresses in the coil bundle by interlocking the adjacent coil layers.

The present invention also provides a method of assembling a coil bundle in substantially uniformly spaced concentric layers in which at least three support members are first longitudinally secured to and along the length of a central dummy core, the members being situated at substantially uniform intervals around the circumference of the core. One part of the support members extends radially from the dummy core surface and is slotted at intervals along its length to retain the coils. The central dummy core is then mounted between power driven fixtures at each end so that the core may be rotated about its longitudinal axis. The core is then longitudinally rotated and tubes are simultaneously wound thereon so as to form a first coil layer whose windings fit into the slots of the support members. Next, additional coil support members are attached to the members secured to the dummy core so that the additional mem-

bers are positioned adjacent to the outer side of the first coil layer and hold the coil windings in the aforementioned slots. Additional tubes are then wound around the dummy core with their coil windings fitting into the slots of the additional coil support members to form a larger diameter second coil layer. Additional still larger diameter coil layers may be wound around the dummy core in the same manner so as to assemble a coil bundle of the desired size. Adjacent coil layers are preferably helically wound in opposite directions for the previously mentioned reasons.

In the accompanying drawings:

FIG. 1 is a plan view looking downwardly on the top of an angle-shaped coil support member of the present invention;

FIG. 2 is an end view of the same coil support member as illustrated in FIG. 1;

FIG. 3 is an enlarged isometric view of a clip which is assembled in pairs for interlocking the coils of adjacent layers together;

FIG. 4 is a perspective view looking downwardly on an assembly of coil supports similar to FIGS. 1 and 2 except that the slot saddles are formed in the opposite direction from the base side of the angle-shaped support members; and

FIG. 5 is a vertical longitudinal section of a bundle of concentrically wound coils embodying one form of the present invention.

Referring more specifically to FIGS. 1 and 2, the coil support member **10** is preferably angle shaped, and may be, for example, a simple, low-cost stamping made from an aluminum sheet.

The support member **10** includes base leg **11** and vertical leg **12** containing slots **13** at uniform longitudinal intervals to receive and support the individual coil windings of a given layer. The slots **13** are preferably contoured at the bottom to correspond to the shape of the coil windings, and a portion of the metal from the base of the slots **13** is formed outwardly into a saddle **14** which distributes the bearing load along the tube and avoids excessive abrasion or scoring on the contact surface. Projections **15** between each pair of adjacent slots **13** are sufficiently long to protrude through the coil layer being supported, and provide a means for mounting an identical support member **10** for the next larger diameter coil layer. Holes **16** stamped in the vertical leg **12** of the support member **10** and between the saddles **14** serve to minimize the longitudinal heat leak along the support member **10**. Holes **16** also permit lateral flow of the heat exchanging fluid outside of the coils, and help to prevent voids in the packing of the embedded-coil regenerator embodiment of the invention. The legs **11** and **12** of the support member **10** are preferably bent so that the vertical leg **12** will extend approximately radially when the base leg **11** is mounted to the curved surface of the dummy core or the next smaller diameter coil assembly as described in more detail below.

The support angles **10** are preferably used in pairs at each support point for improved rigidity. In this case the angles are mounted with their vertical legs **12** placed back-to-back.

FIG. 3 illustrates a clip member **16***a* which is a rectangular stamping with grooves or contours **16***b* pressed in either end to fit around the coil surfaces of adjacent coil bundles. A hole **16***c* is provided in the center of the clip **16***a* for passage therethrough of means for securing the clip assembly.

FIG. 4 illustrates a coil support assembly using the double angle back-to-back construction. This assembly includes support member **10***a* for receiving the individual coil windings of a first coil layer and support member **10***b* receives the coil windings of a second larger diameter coil layer. In the interest of simplicity, only a small number of coils are shown but it is to be understood that in actual practice, coils may be held in any or all of the slots. The coils or tubes **17***a* of the first coil layer are firmly held within the slots by the base leg **11***b* of the support member **10***b* which bears against coils **17***a*. The projections **15***a* of the support members **10***a* are sufficiently long to protrude beyond coils **17***a* of the first layer, and provide means for mounting support members **10***b* of the second coil layer **17***b*. By use of the double angle construction, two back-to-back projections **15***a* are provided, and the two vertical legs **12***b* of the support member **10***b* are rigidly attached to projections **15***a* on either side of such projections by means of rivets **18** extending through holes in the vertical legs **12***b* and the projections **15***a*. Holes **16***d* and projections **15***a* are preferably situated so that the projections do not protrude substantially into the hole area and thereby reduce the effectiveness of such holes. Although riveting has been described as the means of connecting adjacent coil support members, other methods such as spot welding could be substituted.

In FIG. 4 the saddles **14***b* are formed inwardly and in the opposite direction from the base leg **11***b*, whereas in FIG. 2 the saddles are formed outwardly and in the same direction as the base leg. Although both embodiments perform the desired function of distributing the bearing load on the coils, the FIG. 2 form is preferred. This is because the FIG. 4 saddles must be relatively narrow; otherwise, the angles when placed back-to-back will be spaced too far apart and the riveted attachment may not be secure. When the saddles are formed in the same direction as the base leg there is no limit imposed on the saddle width and the bearing load may be more efficiently distributed along the coil lengths.

Adjacent coils **17***a* and **17***b* of the first and second coil layers respectively, are also secured by a pair of clip members **16***a*, shown in detail in FIG. 3, which are contoured on either end to fit around the coils. The clip member assembly is held together by bolt and nut assembly **18***a*, the former passing through clip holes **16***c*. The clips perform two functions by equalizing the torsional forces between the adjacent coil layers and lending torsional rigidity to the entire tube bundle. Concerning the last mentioned function, it was found that a bundle constructed without clips was incapable of transmitting the winding torque from the dmmy core to the periphery of the bundle. After reaching a certain diameter, the assembly became so unstable that continued rotation, opposed by the tangential force of the tubes being wound on the bundle, caused the bundle to collapse and fall apart.

FIG. 5 illustrates a tube bundle according to the present invention which utilizes the previously described components. A build-up method of assembling the coil bundle is employed in which the coils are wound layer upon layer using the coil support members as jigs during the winding operation. The assembly of a coil bundle is begun by horizontally mounting a central dummy core **19** between power driven fixtures **20** at each end so that the dummy core may be rotated about its longitudinal axis. This dummy becomes a permanent core member for the coil assembly and may, for example, be a tube slightly longer than the overall length of the coil bundle. Several angle-shaped inner coil support members **10**, for example four, are welded longitudinally to, and along the length of the dummy core, being spaced at substantially equal intervals around the circumference of the dummy. The vertical legs of inner support members **10** extend radially from the surface of the dummy core **19** and are slotted at close intervals to receive and support the coil windings, as previously described. The dummy core is then rotated and the tube is fed onto the dummy core assembly. By rotation of the dummy, the tube is formed into a coil whose windings fall into the slots provided in the inner coil support members **10**. Wooden slats may be attached longitudinally to the dummy core **19** between the adjacent inner support members **10** so

that each coil winding will be formed in a true circle. These wooden slats are temporary and are removed after each coil layer is completed. When the first layer is formed, four additional coil support members 10 are attached to projections extending through the completed first coil layer 17*a*, and are positioned directly over the inner support members 10. This second set of support members 10 hold the second coil layer 17*b* which is wound in a manner similar to the first layer 17*a*. The second support members 10 bear against the first coil layer 17*a* and hold these windings securely in the slots 13. Additional still larger diameter coil layers may be wound around the dummy core 19 so as to assemble a coil bundle of the desired size.

From the foregoing description, it is seen that the coil support members are stacked one above the other along four radii which extend outwardly from the center of the bundle. When several layers have been wound in this manner, the diameter of the coil layers will have increased so that four support points around their circumferences may not be adequate to position the individual coil windings securely and in parallel relation with each other. When the assembly reaches this stage, four additional coil support members may be attached to the last completed coil layer and are preferably located approximately midway between the original support points. When new support points are established, the innermost support member of such new locations will not have the benefit of a rigid dummy core for anchorage as in the case of the first layer of the bundle. The additional coil support members may be attached to the last completed coil layer, for example, by suitable U bolts or angle clips inserted beneath the windings of the last completed layer. In this manner, eight support points are provided instead of the original four. For still larger diameter coil layers, it may be desirable to add another eight support points between the existing locations. The number of support points which must be provided for the outermost coil layers of the completed coil bundle assembly of course depends on the diameter of such bundle. Clips 16*a* are preferably secured to adjacent coil layers in the previously described manner. If desired, the core 19 may be removed on completion of the coil assembly.

As previously discussed, all of the coils of embedded coil regenerators preferably have the same pressure drop, and the support system of the present invention facilitates attainment of this objective by performing the double function of controlling the tube length and the coil pitch during the winding operation, and of maintaining the desired pitch once the coil layers are formed. In the innermost layer of the smallest diameter, only one coil is preferably provided with the individual laps falling into adjacent slots on the angle support member. When sufficient coils have been wound so that a layer is reached in which the circumference has doubled, two coils each equal in length to the innermost coil are provided for the coil layer with their individual windings falling into alternate slots on the coil support member. However, the circumferences of all coil layers are not necessarily integral multiples of the circumference of the innermost layer. In order to keep the tube length and/or pressure drop of such intermediate circumference layers uniform, it is necessary that one or more of the support slots be skipped in winding each coil of the layer, thereby omitting one or more of the coil turns.

Another feature of the present invention is the winding of adjacent coil layers in opposite directions, i.e., one layer is wound clockwise and the next counterclockwise. One reason for this innovation is that the stresses in the coil bundle may be equalized by interlocking the coil layers, which in turn permits a lighter and simpler support system with less longitudinal heat leak. Adjacent coil layers may be locked together by conventional means, for example, the rigid clips 16*a*. When adjacent coils are oppositely wound, the coils "pull" in opposite directions and when locked together, the forces tending to unwind one coil are opposed by similar but opposite forces in the other coil. If the "unwinding" forces were not opposed but instead placed in the same direction, the lightweight, stacked coil support members would be severely stressed as the entire coil bundle tends to loosen and expand. To avoid this undesirable situation, heavy beam members would be necessary to transfer the torsional loads back to the center dummy core. Such beam members would increase the weight, cost, and complexity of the coil bundle, as well as add to the longitudinal heat transfer through the bundle. Another advantage of the opposite winding technique is improved flow distribution of the cooling air passing through the shell and around the coil bundle. This is because the aforementioned alternative coil support system comprising bulky beam members would distort the gas flow through the packed bed.

From the foregoing description, it may be seen that the present invention provides an economical method of assembling a bundle of coils in substantially uniformly spaced concentric layers, and additionally provides a highly efficient embedded coil regenerator. It is to be noted, however, that the present invention is not limited to regenerator-type construction, but may be applied to any shell-coil type heat exchanger. Also, the terms and expressions which have been employed are used as terms of description and not of limitation, and there is no intention in the use of such terms and expressions of excluding any equivalents of the features described. It should be recognized that various modifications are possible without departing from the scope of the invention.

What is claimed is:

1. A method of assembling a bundle of coils in substantially uniformly spaced concentric layers comprising the steps of securing longitudinally at least three coil support members to, and along the length of a dummy core at substantially uniform intervals around the circumference of such dummy core, one part of the support members extending radially from the dummy core surface and being slotted at intervals along its length to retain the coils; mounting said central dummy core between rotatable fixtures at each end so that the core may be rotated about its longitudinal axis; rotating the core and simultaneously winding tubes around such core so as to form a first coil layer while fitting the windings thereof into the slots of the support members; attaching additional coil support members to the members secured to the dummy core so that the additional members are adjacently positioned to the outer side of said first coil layer and hold the coil windings in said slots; and further rotating said core and simultaneously winding additional tubes around said dummy core while fitting such coil windings into slots of said additional coil support members to form a larger diameter second coil layer.

2. A method of assembling a bundle of coils in substantially uniformly spaced concentric layers according to claim 1, in which clip members are secured to the adjacent coils whereby said coils are interlocked together so as to substantially equalize the torsional forces between adjacent coil layers and provide torsional rigidity to the coil layer assembly.

3. A method of assembling a bundle of coils in substantially uniformly spaced concentric layers according to claim 1, in which the adjacent coil layers are helically wound in opposite directions and clip members are secured thereto whereby they are interlocked together so as to substantially equalize the stresses in the bundle.

4. A method of assembling a bundle of coils in substantially uniformly spaced concentric layers according to claim 1 in which still additional coil support members are longitudinally attached to a coil layer at points intermediate the points at which the inner coil support members are secured to the central dummy core around the circumference of such core, thereby increasing the number of

support points for additional larger diameter coil layers.

5. A method of assembling a bundle of coils in substantially uniformly spaced layers according to claim 1, in which said steps of attaching additional coil supporting members and further rotating said core and simultaneously winding additional tubes around said dummy core while fitting such coil windings into slots of such additional coil support members are repeated to form still larger coil layers around the dummy core so as to assemble a coil bundle of the desired size.

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