United States Patent

[11] 3,575,236

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[54] **FORMED PLATE TUBE SPACER STRUCTURE**
26 Claims, 23 Drawing Figs.

[52] U.S. Cl. **165/162,** 122/510
[51] Int. Cl. **F28b 9/00**
[50] Field of Search 165/69, 178; 122/34; 122/510; 165/162

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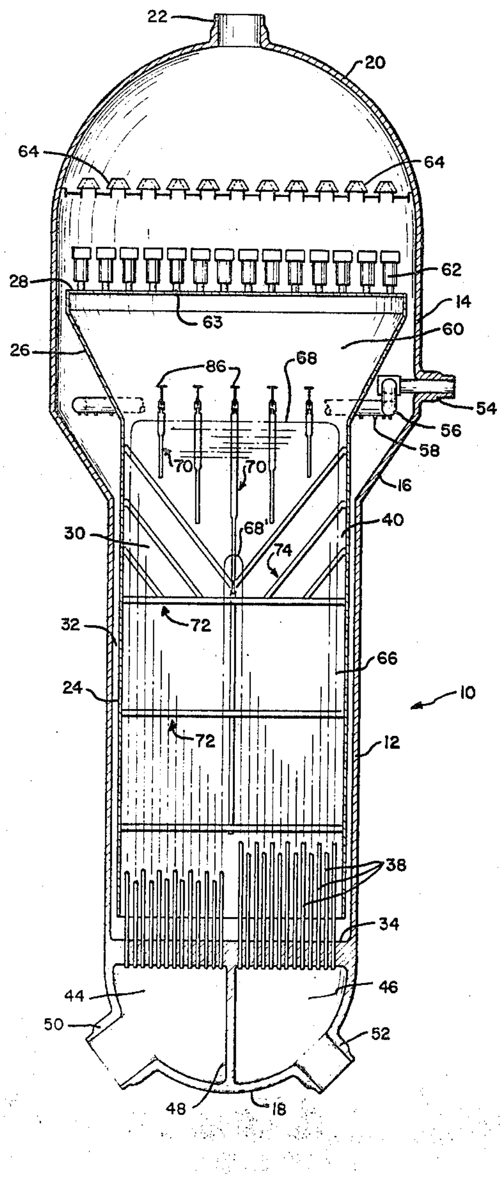
ABSTRACT: Antivibration tube spacer structure for supportingly spacing adjacent tubes of a shell and tube heat exchanger in order to prevent damage to the tubes caused by flow-induced or other mechanically induced vibration. The spacer structure comprises elongated, thin plate members disposed between adjacent tube layers thus to provide engagement at two opposed points on the tubes. Struck out tab projections extending normally from the plate are arranged to engage the tubes on opposite, longitudinally-spaced points that are displaced by 90° from the points of plate engagement.



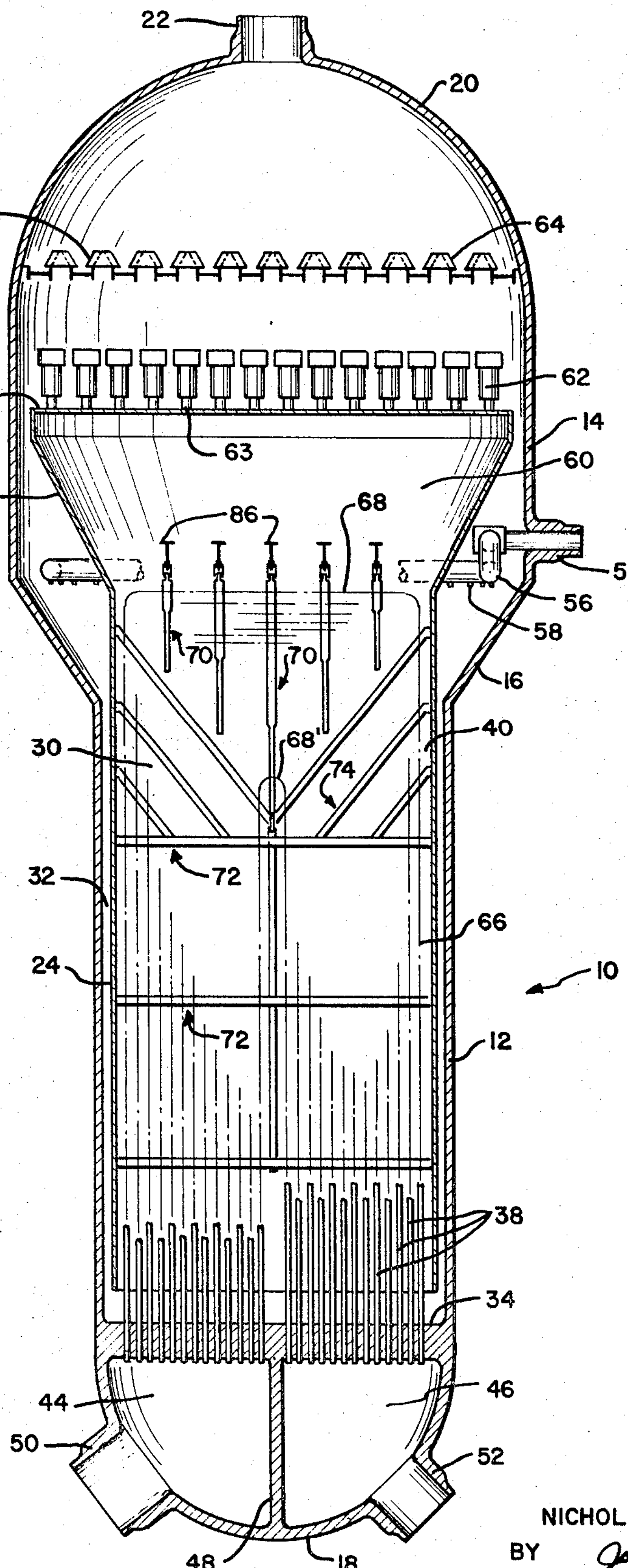


FIG. 1

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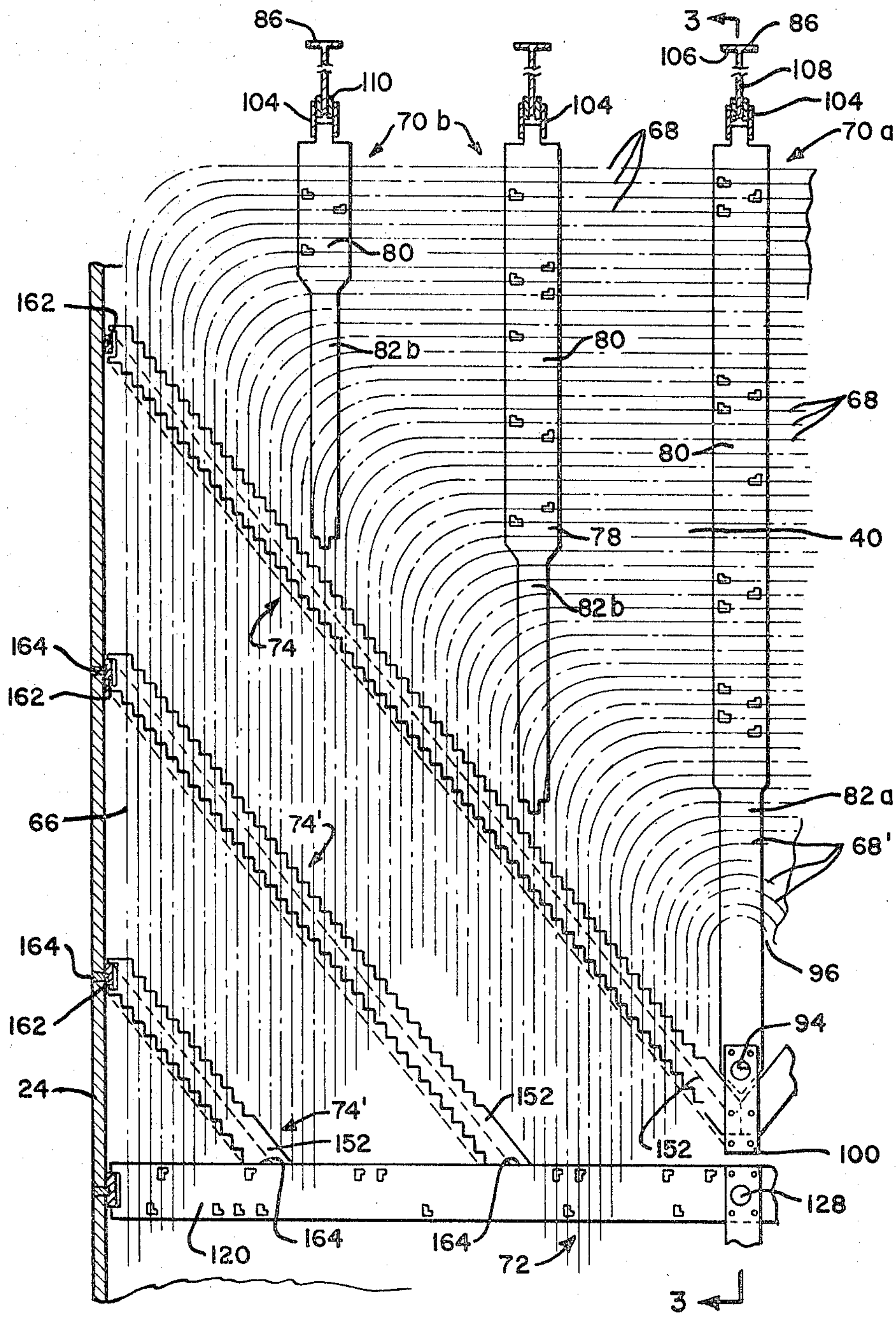

FIG. 2

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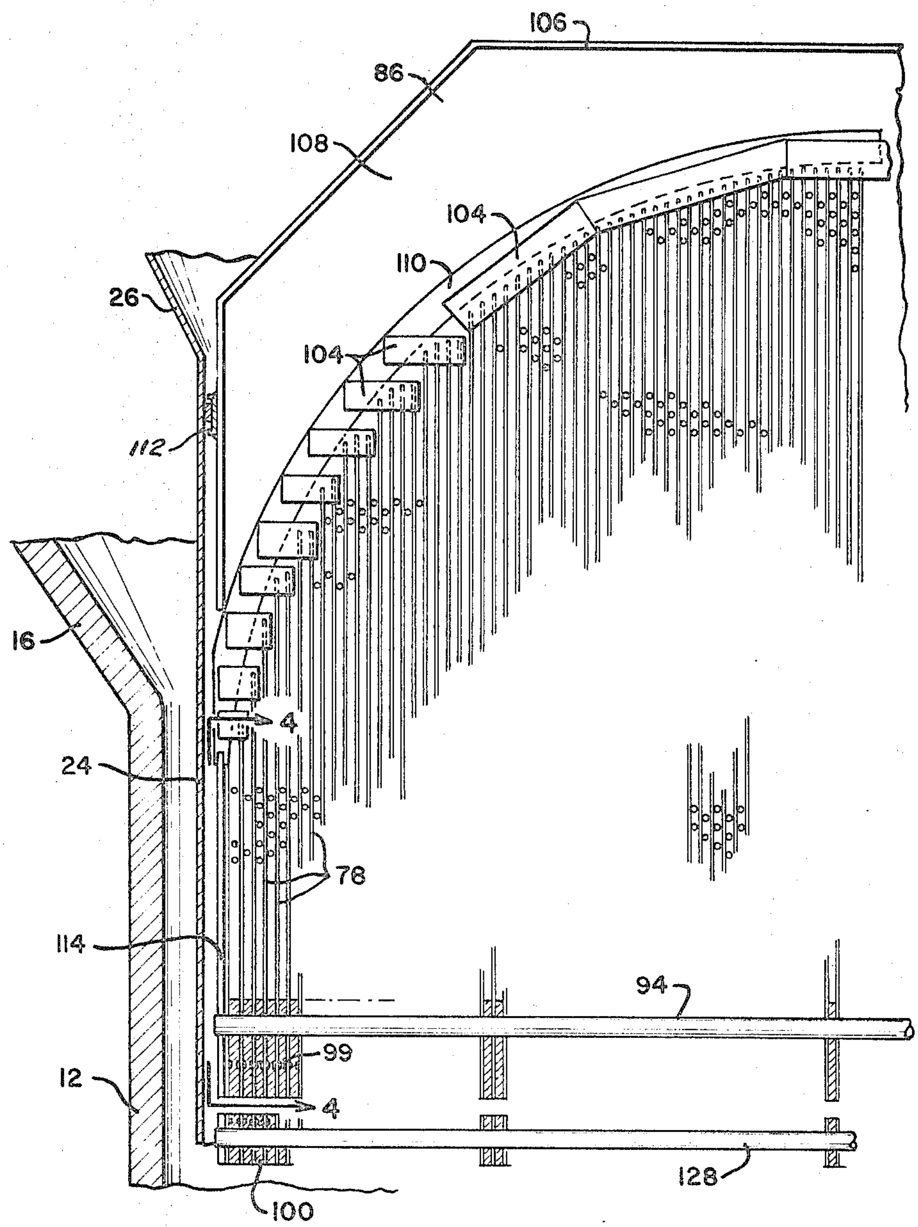

FIG. 3

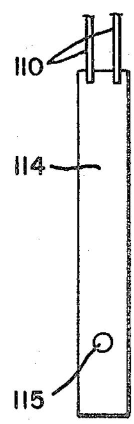

FIG. 4

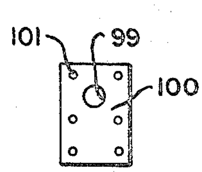

FIG. 5

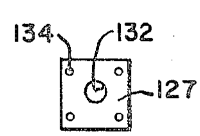

FIG. 6

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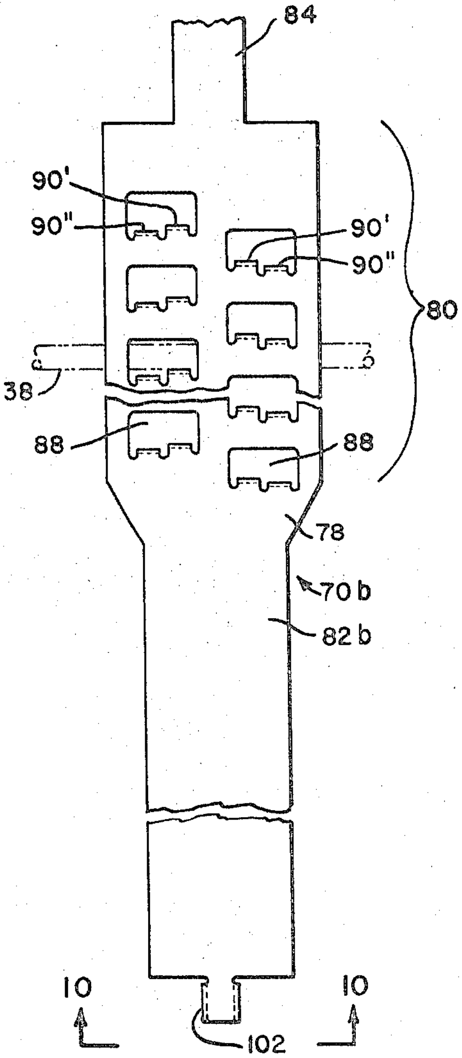

FIG. 9

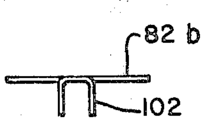

FIG. 10

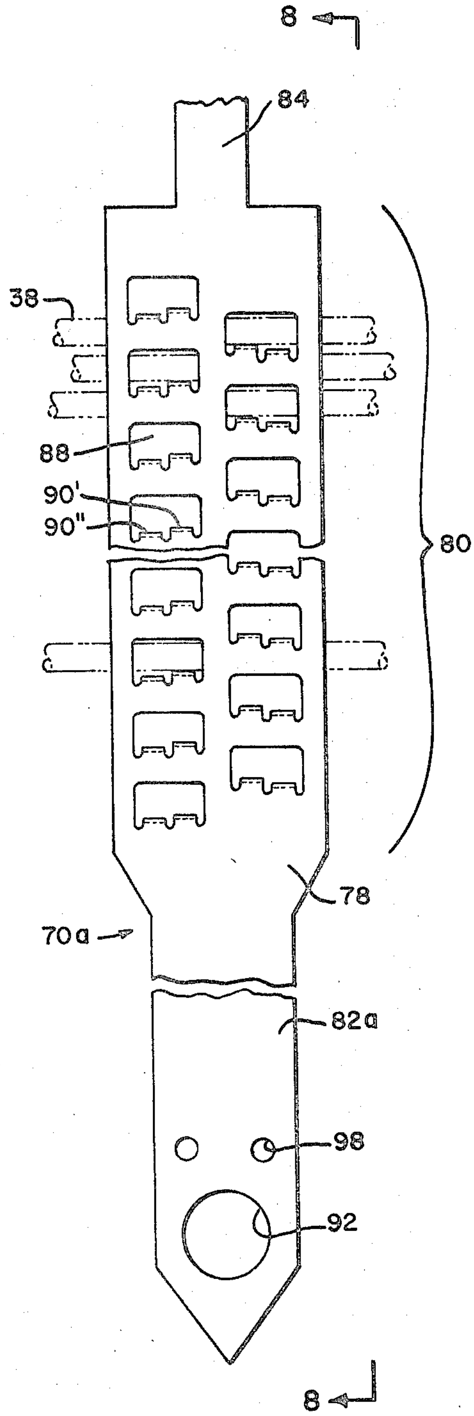

FIG. 7

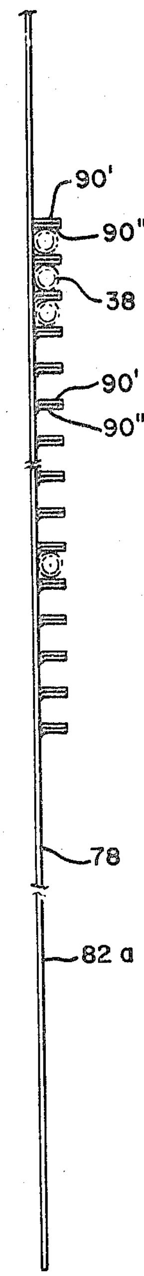

FIG. 8

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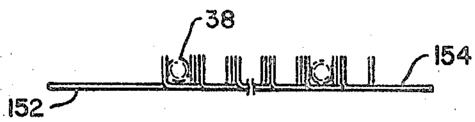

FIG. 23

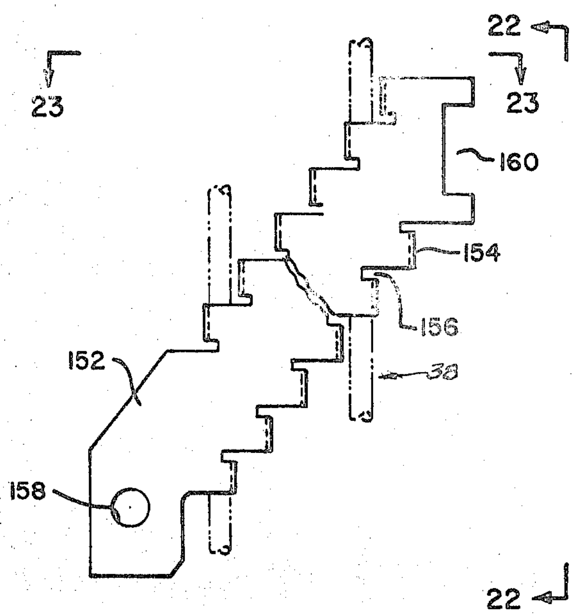

FIG. 21

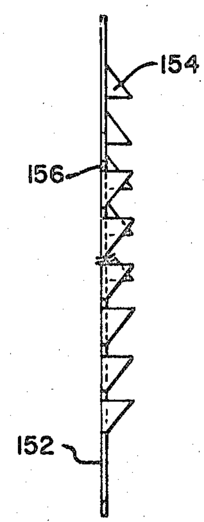

FIG. 22

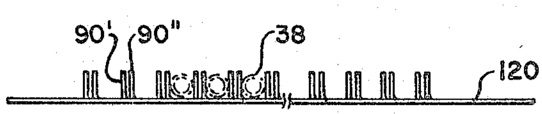

FIG. 12

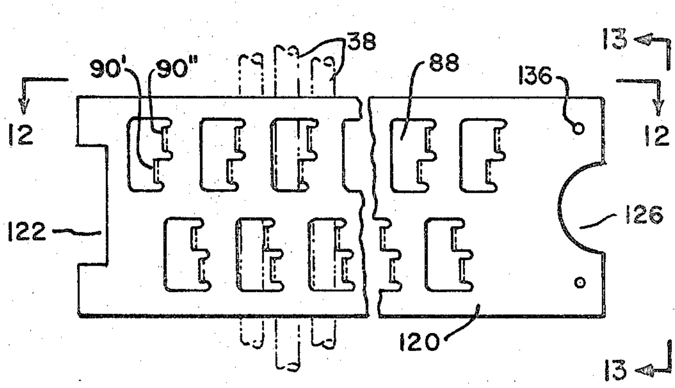

FIG. 11

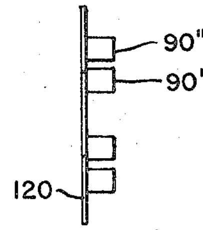

FIG. 13

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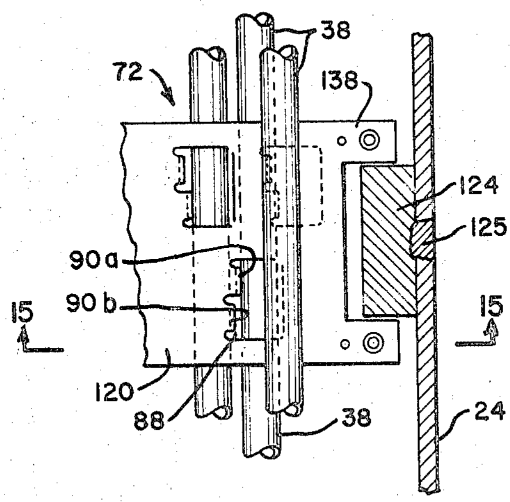


FIG. 14

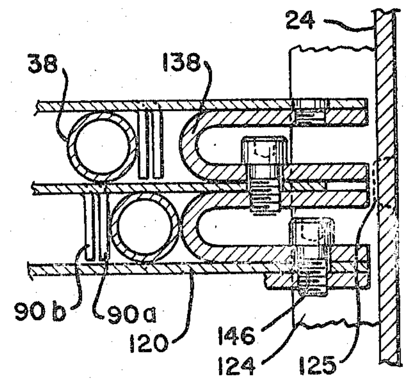


FIG. 16

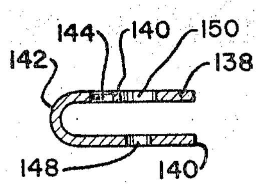


FIG. 18

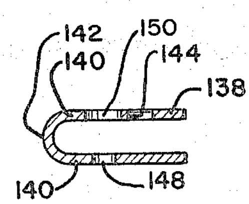
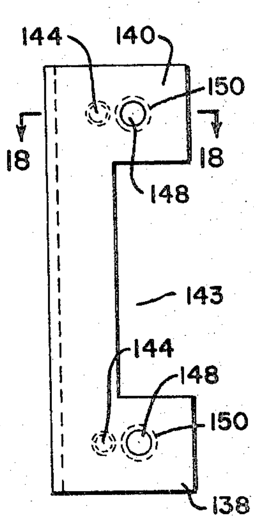


FIG. 20



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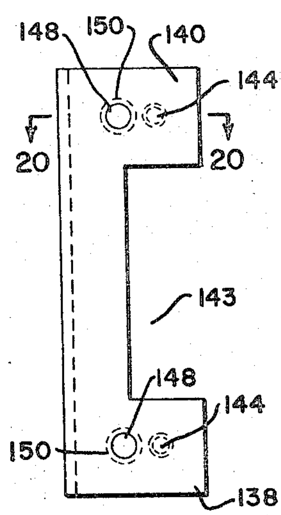

FIG. 19

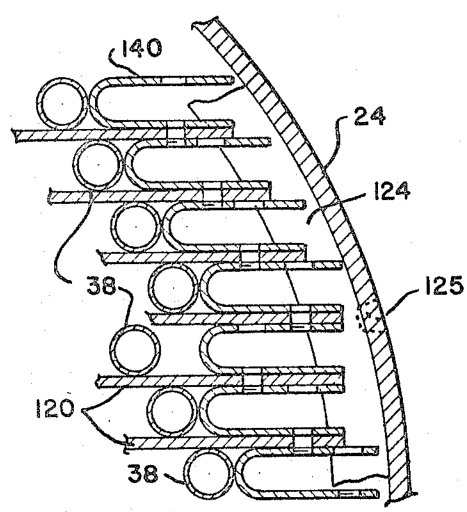

FIG. 15

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FORMED PLATE TUBE SPACER STRUCTURE

BACKGROUND OF THE INVENTION

During recent years shell- and tube-type heat exchangers have been developed to provide a highly efficient means for generating vapor. In this type of heat exchanger a heating medium, such as high temperature water, vapor, petroleum, or gas, among others, is passed through the tubes and gives up a portion of its heat to a vaporizable liquid that is circulated through the chamber about the tubes to exit the shell as saturated or superheated vapor. Such vapor generators provide a great amount of heating surface by employing a large number of small diameter tubes disposed in a tube bundle that substantially fills the vapor generating chamber formed by the enclosing shell.

Vapor generators of this type commonly employ tube bundles formed of layers of U-shaped tubes, the ends of whose legs are secured to a tube sheet disposed at one end of the shell while the nexus portion of the tubes connecting the legs is disposed at the opposite end of the shell. Because such vapor generators, especially those of high capacity, are of considerable axial length, the tubes that comprise the tube bundle are relatively long, thereby rendering them highly susceptible to flow and/or other mechanically induced vibrations. Such vibration is especially pronounced in the area of the nexus portion of the tubes which is the furthest removed from the points of attachment of the tube ends to the tube sheet.

In order to prevent the deleterious effects of vibration, such as damage to the tubes or other component parts of the generator, it is necessary that means be provided to support the tubes against vibration. The tube spacer means that is ultimately employed should satisfy several criteria. It should properly space and secure tubes relative to each other. It should permit relative movement between the tubes and the shell in order to accommodate differential thermal expansion. It should not impair heat transfer between the heating medium and the liquid being vaporized. It should not substantially increase the pressure drop on the vaporizable fluid passing through the shell. And additionally, the tube support means cannot be so complex in design or expensive in fabrication or assembly as to render it economically unattractive.

Tube spacer structures that tend to satisfy the above criteria are embodied in U.S. Pat. applications Ser. Nos. 785,914 to Romanos, filed Dec. 23, 1968 now U.S. Pat. Ser. No. 3,503,440, granted Mar. 31, 1970, and 791,844 to Hill, filed Dec. 13, 1968 now U.S. Pat. Ser. No. 3,545,537 granted Dec. 8, 1970, both of which applications are assigned to the assignee of the present application. While these earlier tube spacer structures have been found to give adequate service, they nonetheless suffer from certain manifest disadvantages. The structure described in Pat. application Ser. No. 791,844 is relatively expensive to fabricate due to the large number of component parts that require machining steps. It further employs members having a greater amount of bulk, thus increasing the weight of the unit and the degree of flow restriction encountered by the fluid flowing in the region of the tube spacer structures. The arrangement of U.S. Pat. application Ser. No. 785,914, on the other hand, while overcoming some of the inadequacies of the former apparatus has the disadvantage of requiring a greater amount of spacing between adjacent tubes to accommodate the tube spacer structure. This deficiency obviously reduces the amount of heat exchange surface that can be housed within a vessel of given volume.

It is tot he improvement of such tube spacer structures, therefore, that the present invention is directed.

SUMMARY OF THE INVENTION

By means of the present invention there is provided tube spacer structure especially adapted for spacedly supporting inverted U-tubes that comprise the tube bundle of shell and tube type vapor generators, or the like. According to one aspect of the invention, the tube spacer between the laterally spaced, vertically extending leg portions of the U-tubes. According to another aspect, the structure is arranged to provide both lateral and vertical spacing between the horizontally extending nexus portions of the U-tubes.

In general terms, the tube spacer structures of the present invention comprises a plurality of elongated, generally flat plate members disposed between adjacent layers of tubes that comprises a tube bundle housed within a heat exchange vessel. The plate members of each tube spacer structure are aligned along a plane that intersects the planes of the tube layers and are mutually secured in a manner which, in one case, permits movement of the spacer structure with respect to the vessel shell under inducement by thermal expansion or contraction of the tubes, and in another case, prevents movement with respect to the shell in which case the tubes are allowed to undergo sliding movement with respect to the plate members.

Each of the plate members is provided with laterally spaced rows of longitudinally spaced, struck out tab projections. The tab projections are staggeredly arranged in pairs with each pair thereof providing laterally spaced, opposed bearing surfaces for supportingly engaging opposite sides of a tube of the adjacent tube layer, thus to engage the tube in one plane of support. Tube engagement in another plane of support is provided by the bearing relation existing between the tubes of the tubes of the respective tube layers and the opposed flat surfaces of the plate members.

By reason of the herein disclosed tube spacer construction, therefore, all of the above-mentioned design criteria are satisfied. The tube spacer structure of the invention embodies a simple design that is inexpensive to fabricate. It provides means for spacingly supporting the tubes of a tube bundle in a manner that prevents any side-to-side movement of the tubes relative to one another while at the same time permitting thermally induced relative movement between the tubes and the enclosing pressure shell. Ample fluid flow area is provided through the structure such that only an insignificant impedance to flow with resulting pressure drop is developed. Additionally, because of the novel tube support arrangement cross flow of vaporizable fluid with respect to the tubes in the region of the tube support structure can occur thereby producing unimpaired heat transfer between the heating fluid conducted through the tubes and the vaporizable fluid.

In addition to the above-cited beneficial characteristics of the novel tube spacer structure of the present invention, another important advantage derived therefrom relates to the ease of assembly of tube bundles within pressure shells that is attendant to its use. Tube spacers employed in heat exchangers of the prior art involved solid plates drilled to permit passage of the tubes or, alternatively, an assembly of intersecting struts commonly referred to as "egg crate" supports. These structures, according to the prevailing practice, were assembled in the shell prior to inserting the tubes. Thereafter, the tubes were assembled in the shell by carefully passing each tube end through the openings in the respective tube spacers and finally attaching the tube ends to the tube sheet. Obviously, a great amount of precision was required in fabricating and aligning the tube spacers in order to permit proper installation of the tubes. Tube spacer structure according to the present invention obviates the need for such close fabrication and alignment tolerances. The plate members that comprise the present structure can simply be arranged as each of the tube layers are assembled within the shell and subsequently affixed together and to the shell thus significantly reducing the time, effort and expense heretofore attendant to the fabrication of the spacers and installation of the tubes.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a vertical section of a shell and tube type vapor generator employing tube spacer structures according to the present invention;

FIG. 2 is a vertical section in enlarged detail of the upper portion of the tube bundle in the vapor generator of FIG. 1;

FIG. 3 is a section taken along line 3–3 of FIG. 2;

FIG. 4 is a view taken along line 4–4 of FIG. 3;

FIG. 5 is a view illustrating one form of tube spacer employed in the present invention;

FIG. 6 is a view illustrating another form of tube spacer employed in the present invention;

FIGS. 7 through 10 are views illustrating plate members comprising one form of tube spacer structure according to the present invention;

FIGS. 11 through 13 are views illustrating plate members comprising another form of tube spacer structure according to the present invention;

FIG. 14 is an enlarged detail view of the means for securing the assembled ends of the plated of FIGS. 11 through 13;

FIG. 15 is a view taken along line 15–15 of FIG. 14;

FIG. 16 is a view similar to FIG. 15 illustrating the elements in greater detail;

FIGS. 17 and 18 are views of one form of attachment clip employed in the invention;

FIGS. 19 and 20 are views of another form of attachment clip employed in the invention; and

FIGS. 21 through 23 are views illustrating plate members comprising yet another form of tube spacer structure according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. 1 of the drawings, there is shown a shell- and tube-type vapor generator 10 incorporating tube support structure constructed according to the present invention. The vapor generator 10 comprises a vertically elongated pressure vessel defined by a lower cylindrical shell 12 and a larger diameter, upper cylindrical shell 14 integrally connected with the lower shell by means of a frustoconical transition member 16. The ends of the vessel are closed, at the bottom by means of hemispherically formed closure head 18 and at the top by a dome-shaped cover 20 containing a vapor outlet nozzle 22. The interior of the pressure vessel contains baffle plate members 24, 26, and 28 that cooperate with the wall of the shells to form an inner vapor generation chamber 30 and an outer, annular downcomer passage 32. At the lower end of the lower shell 12, and intermediate it and closure head 18, is disposed a tube sheet 34 that extends transversely of the axis of the vessel and connects with the wall of the shell. The tube sheet 34 contains a plurality of tube openings adapted to fixedly receive the ends of U-shaped heat exchange tubes 38 that form a longitudinally extending tube bundle 40 substantially filling the lower region of the vapor generation chamber 30. The tube openings extend through the tube sheet 34 to place the tubes 38 in fluid communication with a heating fluid chamber that occupies that region of the vessel enclosed between the closure head 18 and the tube sheet 34 and which is divided into inlet and outlet portions 44 and 46, respectively, by means of a diametral plate 48. The tubes 38 of the tube bundle 40 are arranged such that their opposite ends communicate with one of the respective portions, 44 or 46, of the heating fluid chamber for the through-flow of heating fluid through the tubes. The heating fluid chamber is, in turn, connected to a source of heating fluid (not shown) by means of inlet and outlet nozzles 50 and 52, respectively, that communicate with the respective chamber portions 44 and 46 and thereby effect circulation of heating fluid through the tubes.

Feedwater is supplied to the unit through an inlet nozzle 54 that is shown penetrating the upper shell 14. A ring header 56 connects with the nozzle 54 and serves to distribute feedwater passed through the nozzle about the circumference of the downcomer passage 32 discharging it into the passage by means of downwardly-directed discharge ports 58 that are circumferentially spacedly disposed about the lower surface of the header. Flow of the feedwater from the downcomer passage 32 into the vapor generation chamber 30 is effected by the spaced relationship that exists between the lower end of the baffle plate 24 and the upper surface of the tube sheet 34. Within the vapor generation chamber 30 the feedwater is caused to flow in heat exchange relation with the tubes 38 where heat is extracted from the heating fluid circulated therethrough to cause some of the feedwater to be transformed into vapor. The so-created vapor-liquid mixture flows to the upper region of the vapor generation chamber 30 which is formed as a mixture collection chamber 60 as defined by the cooperation between the baffle plates 26 and 28. Form the mixture collection chamber 60 the flowing mixture is passed to vapor-liquid separator apparatus, a multiplicity of such separators indicated as 62 being mounted upon baffle plate 28 and communicating with the chamber 60 by means of openings 63 provided in the plate. The separators 62 may be of any well-known construction, those shown being of the centrifugal type, and are arranged to discharge separated liquid downwardly upon the baffle plate 28 from whence it is returned to the downcomer passage 32 to be mixed with the incoming feedwater and recirculated through the unit. The separated vapor, on the other hand, is discharged from the separators in the upward direction and passes through appropriate contact drying apparatus 64, from whence it is discharged out the vapor outlet nozzle 22 and conducted to a point of use.

As is common in vapor generators of the disclosed type, the U-tubes that comprise the tube bundle 40 each include a pair of straight, vertically extending leg portions 66 interconnected by a horizontally extending nexus portion 68. In the tube bundle 40 of the unit disclosed herein, the great majority of the tubes 38 have nexus portions that are generally arcuate in shape. All of the tubes 38 are small diameter, thin-walled tubes that are arranged, as shown in FIG. 2, in closely spaced layers with each layer containing a plurality of parallel tubes. In order to provide maximum heat transfer effectiveness, the tube layers of the present arrangement are disposed such that the tubes therein have their centers located on a triangular pitch. Such arrangement places the tubes of each tube layer in alignment with spaces between the tubes of the adjacent layer, thereby to expose a greater amount of heating surface to the flowing vaporizable fluid.

Because the tubes 38 are small diameter, thin-walled members and because the distance between the tube sheet 34 and the top of the tube bundle 40 is extensive, means must be provided for spacedly supporting the tubes along their entire length in order to protect them against damage caused by vibration. Such structure is also required in order to impart sufficient rigidity to the tubes to permit them to maintain their mutually spaced relationship in the tube bundle. Tube spacer structure adapted to perform these functions and constructed according to the present invention are illustrated in FIGS. 1 and 2 of the drawing as being of three generally forms. The first form, indicated generally as 70, is a vertically elongated arrangement disposed in the upper region of the tube bundle 40 and adapted to space the horizontally extending nexus portions 68 of the U-tubes. The second form, indicated as 72, is generally similar in regard to its tube support structural configuration to the arrangement 70. Apparatus constructed according to this form of the invention however are vertically spaced throughout the height of the tube bundle and comprise horizontally extending members that serve to space the leg portions 66 of the tubes 38. The third form of apparatus, indicated as 74, provides lateral spacing between adjacent tube layers in that region of the tube bundle 40 that cannot accommodate either of the structures 70 or 72 due to the proximity of the bends between the leg and nexus portions of the tubes. This latter form of the invention is comprised of obliquely arranged members disposed adjacent the tube bends and intermediate the tube spacer apparatus 70 and 72.

The tube spacer structure 70 of the present invention is described with particular reference to FIGS. 2 through 9 of the drawing. As shown in FIG. 2, the tube spacer structure that comprises this form of the invention is embodied in two substantially similar arrangements, indicated in the FIG. as 70*a* and 70*b*. Tube spacer structure 70*a* is disposed in the center of the upper region of the tube bundle 40 and structure 70*b* is outwardly spaced from the structure 70*a* on both sides thereof. The structures 70*a* and 70*b* are substantially similar in construction details, differing only as to the means employed to secure the lower end of the plate members that comprise the structures as hereinafter set forth. On view of the similarity that exists between the structures 70*a* and 70*b*, the description that follows, while being particularly directed toward the arrangement 70*a*, will apply equally to arrangement 70*b* except wherein indicated otherwise.

Tube spacer structure 70*a* comprises a plurality of elongated, vertically extending, flat members 78 that are interposed between each of the adjacent layers of tubes 38 that comprise the tube bundle 40. The plate members 78 are disposed in an aligned row that traverses the full width of the upper region of the tube bundle and extends perpendicularly to the axis of the nexus 68 of the tubes. Each plate member 78 is comprised of two principal portions, a tube supporting portion 80 that occupies that portion of the plate member that is intersected by straight nexus portions of the tubes 38 in the adjacent tube layer and a subtending extension portion 82 that traverses the arcuately formed bend portions of the U-tubes. At their upper ends the plate members are provided with substantially centrally disposed tongue extensions 84 that are formed of reduced width for reception in structure members 86 as hereinafter described.

As best shown in FIGS. 7 and 9 the tube supporting portion 80 of the plate members 78 contains a pair of parallel rows of generally E-shaped openings 88 that are arranged in staggered relation on opposite sides of the longitudinal axis of the plate. The openings 88 are formed by stamping or otherwise removing material from the plate in the shape of an E thereby providing an opening that includes a pair of tabs 80′ and 90″. The tabs 90′ and 90″ are of unequal length with the innermost tab 90′ in each set being longer than the outermost tabs 90″ by an amount approximately equal the space between adjacent tubes 38 in each tube layer. As best shown in FIG. 8, the tabs 90 are struck out from the plane of the plate members 78 to a position substantially normal thereto, thus defining projections adapted to engage the surface of the tubes.

When the plate members 78 are assembled between adjacent tube layers of the tube bundle 40 each tube 38 will be engaged by opposing faces of a pair of tab projections 90′ and 90″, each being associated with alternate openings 88. For example, as shown in FIG. 7, a typical tube 38 is vertically restrained on its underside by the upper surface of the tab projection 90′ associated with an opening 88 in the row to the left of the plate axis and on the other side by the under surface of the tab projection 90″ associated with the alternate opening 88 in the opposite row. The remaining tubes 38 are similarly restrained by a tab projection 90′ on one side of the axis of the plate member 78 and a tab projection 90″ on the other side.

By means of this arrangement each tube 38 is engaged by tab projections at axially spaced points along the tube surface thereby providing ample flow area for fluid to pass vertically along serpentine flow paths through the region occupied by the tube spacer structure.

In the preferred embodiment of the invention the length of the projected tabs 90′ and 90″ is approximately equal to the diameter of the tube being supported such as to locate the end edges of the respective tabs in longitudinal alignment and, when assembled, in abutment with the facing surface of the adjacent plate member. By so forming the tabs, means are provided to stiffen the members along their length.

The subtending extension portion of the plate members 78 that comprise the tube spacer structure 70*a* is indicated as 82*a* in FIG. 7 and provides means for anchoring each plate member at its lower end. It comprises an imperforate extension of the body of the plate member extending across that area of each tube layer that is occupied by tube bends as shown in FIG. 2. At its lower end, the extension portion 82*a* is provided with an enlarged diameter aperture 92 for attaching the plate member to a connector rod 94 that extends through a diametrally extensive area 96 of the tube bundle that is void of tubes. A second set of apertures 98 of smaller diameter than the aperture 92 are provided to accommodate dowels 99 for attaching the plate members to spacer plats 100 shown in FIG. 5 The spacer plates 100 are provided with through-openings 101 and 103 to accommodate the connector rod 94 and dowels 99 and are formed of a thickness that is approximately equal to the diameter of the tubes in order to maintain the proper spacing of the plate members at their lower end.

The extension portions indicated as 82*b* of the plate member 78 that comprises the tube spacer structure 70*b* are provided at their lower ends with a formed U-shaped clip 103 adapted to engage the vertically extending leg portions 66 of a tube in the adjacent tube layer, thus to secure the lower ends of the plate members that comprise this form of the arrangement.

The upper ends of the tube spacer structures 70*a* and 70*b* are secured to the baffle plate 24 by attachment to structural members 86 that overlie the upper end of tube bundle 40 and which connect at their opposite ends to the baffle plate. As shown in FIG. 3 the structural members comprise a flange 106 and a depending web 108, the latter being formed on its lower edge as an arc of a circle to conform generally to the shape of the upper end of tube bundle 40. The upper ends of the plate members 78 that comprise the tube spacer structures are secured to the structural members 86 by means of tongue extensions 84 disposed at the upper end of each of the plate members and which are adapted to be weldedly attached to the respective structural members. Attachment is effected by arranging the tongue extensions 84 between pairs of oppositely spaced retainer plates 104 that are spacedly connected to the web 108 by means of opposed arcuate spaced plates 110 and welding the tongue extensions to the retainer plates.

In order that thermally-induced vertical movement between the tube support structures 70*a* and 70*b* can occur connection of the ends of the structural members 86 to the shell 24 is effected by means of a slidable connector, indicated as 112 in FIG. 3. Moreover, in the case of tube spacer structure 70*a*, the opposite ends of the arcuate spacer plates 110 attach a depending support plate 114 having an opening 115 adjacent its lower end for reception of the respective ends of connector rod 94.

By means of this embodiment of the invention, therefore, there is provided a simple, inexpensive tube spacer arrangement that is effective to spacingly support the nexus portions 68 of tube 38 in the upper region of the tube bundle 40. Because the tubes 38 of each tube layer are supported on their opposite lateral sides by the opposed surfaces of adjacent plate members 78 and on their top and bottom sides by opposing surfaces on tab projections 90′ and 90″ vibration-induced motion in the tubes is prevented. Flow of vaporizable fluid across the tubes 38 in the region occupied by the structures 70*a* and 70*b* will not be adversely impeded due to the flow space provided through the structures by the lateral spacing between the tab projections 90′ and 90″ supporting each tube.

In the second form of the invention, indicated as 72 in FIGS. 1 and 2, tube spacer structures are employed for laterally spacing the vertically-extending leg portions 66 of the U-tubes 38 at spaced intervals along their length. With particular reference to FIGS. 11 through 13, the tube spacer structures 72 each comprise a plurality of horizontally disposed plate members 120 that are provided with the same oppositely spaced rows of generally E-shaped openings 88 and struck-out tab projections 90′ and 90″ as contained in the plate members 78 of the earlier described embodiment indicated as 70. As best shown in FIGS. 2 and 15, the plate members 120 are disposed between adjacent layers of tubes and extend from the outer periphery of the tube bundle 40 substantially to the middle thereof. At their outer ends the plate members are provided with a rectilinear recess 122 for attachment to an annular band or ring 124 that encircles the tube bundle and is plug welded as at 125 or otherwise fixedly attached to the downcomer baffle 24. The inner ends of the plate members 120 are provided with a semicircular recess 126 in order to adapt the ends for connection to spacer plates 127 (FIG. 6) that are mounted on a connector rod 128 that extends through the void 96 that defines the middle of the tube bundle. The connector rod 128 is spaced below the connector rod 94 and is attached as by means of welding at its opposite ends to the annular band 124 that surrounds the structure.

The spacer plates 127 as shown in FIG. 6 are provided with an enlarged central aperture 132 to accommodate reception of the plates on the rod 96. The spacer plates 127 also contain two pair of oppositely spaced small diameter apertures 134 that are adapted to receive dowels which extend through accommodating apertures 136 located adjacent the inner end of the plate member so as to effect attachment of the plate member to the spacer plates.

In order to maintain the spaced relation between the plate members 120 at their outer ends, connection of these ends of the plate members to the annular ring 124 is achieved by threadedly connecting the respective members to attachment clips 138. The clips 138 are U-shaped in section and have leg portions 140 of varying lengths in order that the clip bend 142 in most cases can abut the outermost tube in the tube layer with the legs weldedly engaging the annular ring 124. To facilitate engagement of the leg portions 140 with the annular band 124, the former is provided with a rectilinear recess 143 that conforms generally to the recesses 122 in the plate members 120. Each clip 138 is provided with upper and lower sets of threaded and unthreaded apertures for reception of threaded connector 146 that serve to connect the plate members 120 in sandwiched relation between adjacent clips. The apertures in each set consist of a threaded aperture 144 to receive the threaded shank of connector 146, and unthreaded aperture 148 to permit passage of the shank, and a somewhat enlarged diameter unthreaded aperture 150 to permit access to the connector by an operating tool. The threaded aperture 144 and enlarged unthreaded aperture 150 are in one leg of the clip and the remaining unthreaded aperture 148 is located in the other leg in alignment with the aperture 150.

Due to the crowded condition of the region of the unit in which the attachment clips are located, it is necessary to employ clips having alternating aperture arrangements in their legs in order to accommodate the connectors 146. The two forms of attachment clips are illustrated in FIGS. 17 and 18 and 19 and 20. In the attachment clip 138 illustrated in FIGS. 16 and 17, the threaded aperture 144 is located closest the clip bend with the other apertures 148 and 150 being remote therefrom, while in the arrangement of FIGS. 18 and 19 the positions of these apertures are reversed.

When the tube spacer structures 72 are assembled in the tube bundle 40 the leg portions 66 of each tube 38 in the respective tube layers are prevented from moving in relation to the tubes of the adjacent tube layers by the interposition of the plate members 120. Likewise relative movement between tubes 38 within the respective tube layers is prevented by the engagement of the tubes by projected tabs 90' and 90'' in a manner similar to that of the embodiment indicated as 70. Thermally induced relative movement of the legs 66 of tubes 38 is permitted in this embodiment of the invention by the relative vertical sliding motion that is permitted to exist between the tube legs and the plate members 120.

A third embodiment of the invention is shown in detail in FIGS. 21 through 23 of the drawing. This embodiment, indicated generally as 74 in FIGS. 1 and 2, adopts the concept of the invention in tube spacer apparatus capable of being utilized in that region of the tube bundle 40 adjacent the tube bends that connect the leg portions 66 and nexus portions 68 and that can accommodate neither of the previously described structures 70 or 72. The tube spacer structures 74, six of which are shown in FIG. 1 as being employed in the described embodiment, each comprise a plurality of aligned, obliquely set, thin, flat plate members 152 arranged in the spaces between each tube layer. Along the longitudinal side edges of each plate member 152, projected tabs 154 are struck out from the body thereof and offset normally thereto to form tube spacer elements in a fashion not substantially unlike that of the tabs 90 in the previously described structures. In fabricating the tabs 154 a series of lateral slots 156 are first cut into the plate members 152 at longitudinally spaced points along the length of both side edges thereof. The slots 156 are angularly disposed with respect to the side edges to an extent that presents them in generally horizontal disposition when the members 152 are assembled in the tube bundle. The plate material between each of the slots 156 is then offset to a position normal to the surface of the plate members and along lines at right angles to the edges of the slots thus to form the tube-engaging tabs 154.

As best shown in FIG. 21, the offset tabs 154 along opposite side edges are arranged such that each tube 38 in the respective adjacent tube layer is engaged on opposite sides at axially spaced points by alternately spaced tabs. In this way, each of the tabs 38 is engaged on two oppositely spaced sides in one plane of support by the tabs 154. In the other plane of support, which is offset by 90° from the first plane, each tube will be engaged on opposite sides by the surface of the adjacent plate members 152.

As is evident from examination of FIG. 2, two slightly different forms of tube spacer structures 74 are employed in the described vapor generator arrangement. The structures 74 located nearest the tube bends have their lower end edges attached to the spacer plates 100 that space the plate members 78 of the central vertically extending tube spacing structure 70. Attachment of the plate members 152 to the plates 100 is effected by dowel connectors for which apertures 158 are provided adjacent the lower ends of the members 152. At the opposite end, each plate member 152 is provided with a rectilinear recess 160 to accommodate attachment of plate members to an annular band 162 that encircles the tube bundle thereby securing the upper ends of the plate members.

In order to permit thermally induced movement of the tubes 38, the band 162, in the described embodiment, is not attached to the inner surface of the downcomer baffle 24, but instead is arranged for sliding contact with the inner surface of that baffle. In this way these tube spacer structures are permitted to undergo vertical movement with the tubes 38 between the latter's expanded and contracted position.

The plate members 152 of the remaining tube spacer structures indicated as 74' in FIG. 2 have the same general configuration as those of the structures illustrated in FIG. 20 with the exception that their lower ends are provided with a simple straight edge 164 (FIG. 2) which is adapted to rest on the upper side edge of the adjacent plate member 120 disposed in the uppermost tube spacer structure 72. It should also be noted that the annular bands 162 that engage the upper ends of the plate members 154 of these lower tube structures 74 are fixedly secured at the inner surface of the downcomer baffle 24 by means of a plug weld 164 or the like. With the plate members 152 and these lower tube spacer structures 74 being fixedly secured with respect to the shell, the expansion and contraction of the tubes is accommodated throughout the structures by the relative sliding movement that is permitted to occur between the tubes 38 and the struck out tabs 154 on these members.

There has thus been described a tube spacer structure that is effective to supportingly space the tubes of a tube bundle against the harmful effects of vibration. Tube spacer structure according to the invention, as compared with spacers of the prior art, is much simpler in design, less costly to fabricate and install and provides a greater amount of fluid flow area through the structure thus to reduce the amount of pressure loss normally expected from the presence of tube spacers.

It will be understood that various changes in the details, materials, and arrangements of parts which have been herein described and illustrated in order to explain the nature of the invention may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims.

I claim:

1. In a heat exchanger having a tube bundle, the improvement comprising between adjacent tubes in a tube bundle including a plurality of spaced layers of aligned, mutually spaced, parallel tubes, said tube spacer structure comprising:

a. a plurality of elongated, flat plate members, each being disposed between the respective tube layers and alignedly arranged in a row that intersects the planes of said tube layers;

b. said plate members being each provided with a plurality of tab projections extending from the surface thereof, said tab projections being arranged in rows that are oppositely spaced from, and extend substantially parallel to, the longitudinal axes of the respective plate members;

c. the tab projections on each of said plate members being arranged in pairs for engaging said tubes, each of said pairs consisting of two oppositely facing tab projections longitudinally spaced from one another by a distance corresponding substantially to the diameter of the engaged tube, one of the tab projections in each pair emanating from one of said rows and the other of said tab projections emanating from the other row whereby said tubes are each engaged at opposite, axially spaced points; and

d. means for retaining said plate members in mutually fixed relation.

2. Tube spacer structure as recited in claim 1 wherein said flat plate members are disposed with their opposite faces in bearing relation with the tubes of adjacent tube layers.

3. Tube spacer structure as recited in claim 2 wherein the bearing surfaces presented by said tab projections are in planes substantially normal to said plate members.

4. Tube spacer structure as recited in claim 3 wherein said plate members are angularly disposed with respect to the axes of the engaged tubes.

5. Tube spacer structure as recited in claim 4 wherein said tab projections are provided with their free end edges in abutting relation to the adjacent plate member.

6. Tube spacer structure as recited in claim 4 wherein the bearing surfaces presented by said tab projections are in planes substantially normal to the longitudinal axes of the respective plate members.

7. Tube spacer structure as recited in claim 4 wherein the bearing surfaces presented by said tab projections are in planes disposed obliquely with respect to the longitudinal axes of the respective plate members.

8. Tube spacer structure as recited in claim 6 wherein said tab projections are arranged in groups of two, said groups being disposed in oppositely spaced rows on alternate spacing and the tab projections in each group being disposed in side-by-side relation with the bearing surfaces presented thereby being longitudinally spaced from one another by an amount substantially equal to the desired spacing between the tubes in the adjacent tube layers.

9. Tube spacer structure as recited in claim 8 wherein said groups of tab projections are defined by stamped, generally E-shaped openings

10. Tube spacer structure as recited in claim 7 wherein the longitudinal side edges of said plate members are formed with tab projections spaced therealong, each of said tab projections on each side edge having a complementary tab projection on the other side edge to define a pair, and the bearing surfaces presented by each of said pairs of tab projections being in opposing, longitudinally spaced relation to one another and mutually laterally spaced by an amount equal to the diameter of the tube to be engaged thereby.

11. A heat exchanger for the indirect transfer of heat from one fluid medium to another comprising, in combination:

a. an elongated pressure shell;

b. a tube sheet transversely arranged within said shell and dividing the same into a first chamber and a second chamber;

c. a tube bundle including a plurality of spaced layers of aligned, mutually-spaced, parallel tubes disposed within said first chamber with the ends of said tubes connected to said tube sheet and in fluid communication with said second chamber;

d. means including said second chamber for circulating one of said fluids through said tubes;

e. means for supplying the other of said fluids to said first chamber to flow over said bundle of tubes; and

f. tube spacer structure means for maintaining the spacing between adjacent tubes in said tube bundle, including:

i. a plurality of elongated, flat plate members, each being disposed between the respective tube layers and alignedly arranged in a row that intersects the planes of said tube layers;

ii. said plate members being each provided with a plurality of tab projections extending from the surface thereof, said tab projections being arranged in rows that are oppositely spaced from, and extend substantially parallel to, the longitudinal axes of the respective plate members;

iii. the tab projections on each of said plate members being arranged in pairs for engaging said tubes, each of said pairs consisting of two oppositely facing tab projections longitudinally spaced from one another by a distance corresponding substantially to the diameter of the engaged tube, one of the tab projections in each pair emanating from one of said rows and the other of said tab projections emanating from the other row whereby said tubes are each engaged at opposite, axially spaced points; and

iv. means for retaining said plate members in mutually fixed relation.

12. The combination as recited in claim 11 including tubes in said tube bundle extending substantially parallel to the axis of said pressure shell and a plurality of tube spacer structures axially spaced throughout the length of said tubes, each of said tube spacer structures including plate members extending transversely of the axis of said pressure shell and having tab projections disposed in two oppositely spaced rows along the length of said plate members, said tab projections being substantially normally offset from the surface of said plate members and presenting tube bearing surfaces that are angularly disposed with respect to the longitudinal edges of said plate members, the plate members of the respective tube spacer structures being fixedly secured with respect to said pressure shell and the tab projections engaging said tubes for sliding movement therebetween.

13. The combination as recited in claim 12 wherein said tube spacer structures each comprise horizontally elongated plate members, each of said plate members having tab projections arranged in groups of two, said groups being disposed in oppositely spaced rows on alternate longitudinal spacing and the tab projections in each group being disposed in side-by-side relation, the bearing surfaces presented by the respective pairs of tab projections being mutually vertically spaced and laterally opposed to engage said tubes on opposite sides thereof, said plate members extending beyond the outer periphery of said tube bundle, an annular band retaining the extended ends of said plate members, and means for fixedly securing said annular band with respect to said pressure shell.

14. The combination as recited in claim 13 wherein said groups of tab projections are each defined by a stamped, generally E-shaped opening.

15. The combination as recited in claim 13 wherein the plate members of said tube spacer structures have their inner ends terminating substantially midway through said tube bun-

dle, a diametrally extensive connector rod extending through said tube bundle transversely of the ends of said plate members, means for securing the inner ends of said plate members to said connector rod, and means for fixedly securing the ends of said connector rod with respect to said pressure shell.

16. The combination as recited in claim **12** wherein said tube spacer structures each comprise elongated plate members, obliquely disposed with respect to the axis of said pressure vessel, the longitudinal side edges of said plate members being formed with tab projections spaced therealong, each of said tab projections on each side edge having a complementary tab projection on the other side edge to define a pair, the bearing surfaces presented by each of said pairs of tab projections being mutually vertically spaced and laterally opposed to engage said tubes on opposite sides thereof, said plate members extending beyond the outer periphery of said tube bundle, and an arcuate band surrounding said tube bundle and retaining the extended ends of said plate members in mutually fixed relation.

17. The combination as recited in claim **16** including means for fixedly securing said arcuate band with respect to said pressure shell.

18. The combination as recited in claim **16** wherein said arcuate band is axially movable with respect to said pressure shell.

19. The combination as recited in claim **18** wherein the plate members of said tube spacer structures have their inner ends terminating substantially midway through said tube bundle, a diametrally extensive connector rod extending through said tube bundle transversely of the ends of said plate members, means for securing the inner ends of said plate members to said connector rod, and means for vertically moving said connector rod with respect to the axis of said pressure shell.

20. The combination as recited in claim **11** wherein the tubes of said tube bundle are generally U-shaped having the nexus portions interconnecting the legs of said tubes disposed

uppermost in said tube bundle and wherein said tube spacer structures engage the nexus portions of said U-tubes and each comprise vertically extending plate members having the tab projection bearing surfaces of each of said pairs engaging the nexus portion of said tubes at axially spaced points therealong.

21. The combination as recited in claim **21** wherein said tab projections are arranged in groups of two, disposed in side-by-side relation, said groups being disposed in oppositely spaced rows on alternate longitudinal spacing, the bearing surfaces presented by the respective pairs of tab projections being mutually laterally spaced and vertically opposed to engage the nexus portion of the tubes on opposite sides thereof.

22. The combination as recited in claim **21** wherein said groups of tab projections are each defined by a stamped, generally E-shaped opening.

23. The combination as recited in claim **21** including means disposed above the upper end of said tube bundle for suspendedly supporting said plate members in mutually fixed relation, said means comprising a structural member overlying the upper ends of said plate members, means for securing said ends of said plate members to said structural member and means for attaching the ends of said structural member with respect to said pressure shell.

24. The combination as recited in claim **23** wherein said structural member attaching means provides for vertical movement of said structural member with respect to said pressure shell.

25. The combination as recited in claim **24** wherein the lower ends of said plate members extend into said tube bundle, terminating below the lowermost of said nexus portions, and including a diametrally extensive connector rod extending through said tube bundle below the nexus portions of the tubes thereof, and means for securing the lower ends of said plate members to said connector rod.

26. The combination as recited in claim **24** wherein the lower ends of said plate members are disposed adjacent the leg portions of said tubes and include clip connectors for engaging said lower ends to said leg portions.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,575,236 Dated April 20, 1971

Inventor(s) Nicholas D. Romanos

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

Column 1, line 68, replace "tot he" with --to the--;

Column 2, line 1, after "spacer" insert --structure is so arranged as to provide anti-vibration support spacing--;

Column 4, line 33, after "portions" insert --68--;

Column 4, line 33, after "generally" insert --straight. Those tubes, indicated as 68', however, that lie in the innermost tube rows may be formed, as shown, with nexus portions that are generally--;

Column 5, line 9, replace "On" with --In--;

Column 5, line 15, after "flat" insert --plate--;

Column 5, line 37, replace "80'" with --90'--;

Column 5, line 40, after "equal" insert --to--;

Column 6, line 8, replace "plats" with --plates--;

Column 6, line 16, replace "103" with --102--;

Column 6, line 38, replace "spaced" with --spacer--.

Column 12, line 6, replace "claim 21" with -- claim 20 --.

Signed and sealed this 1st day of August 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents