Aug. 10, 1965 E. VOGT ETAL 3,199,582

HEAT EXCHANGER TUBE ANTI-VIBRATION STRUCTURE

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Fig. 1.

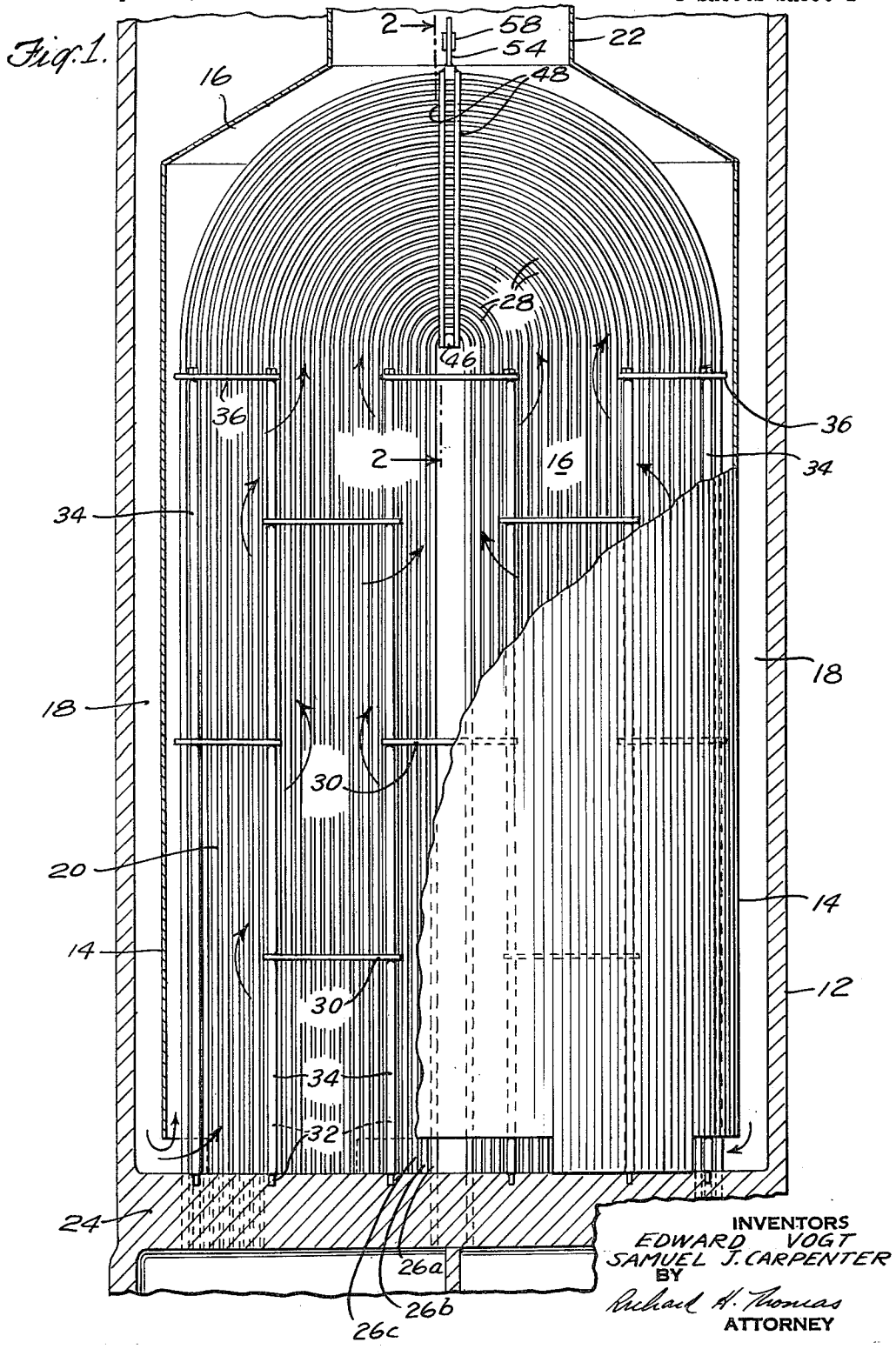

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Fig. 2.

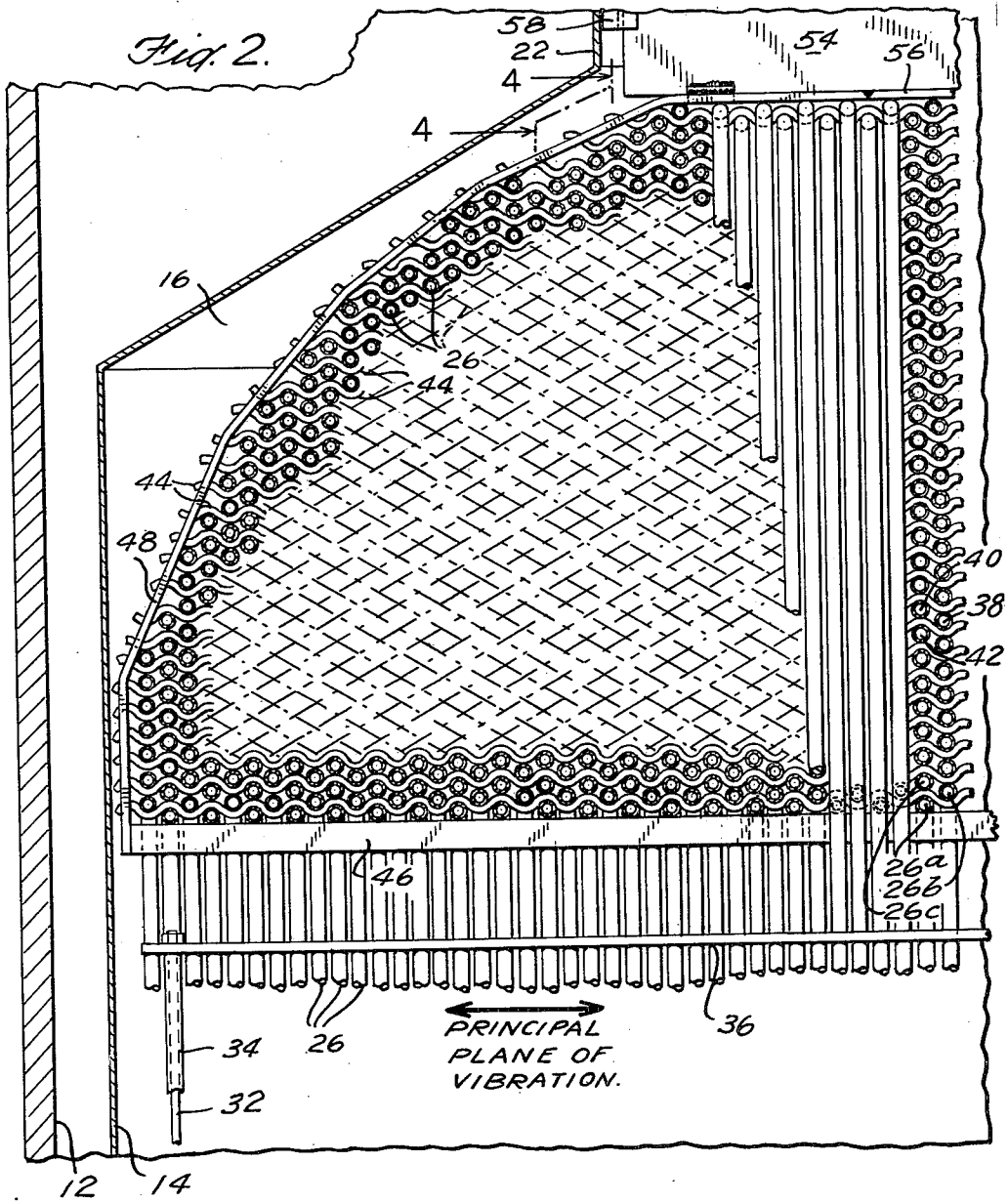

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Fig. 3.

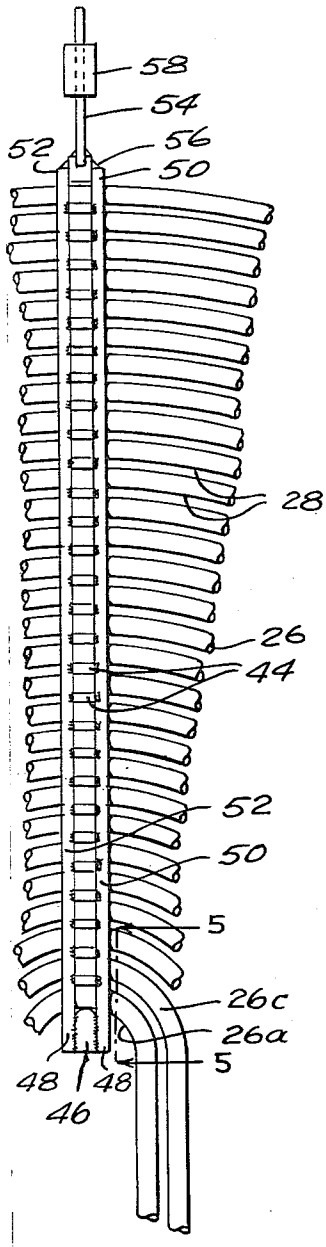
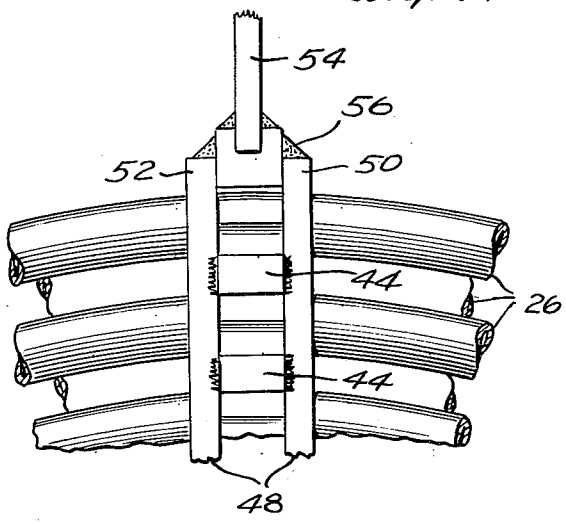


Fig. 4.



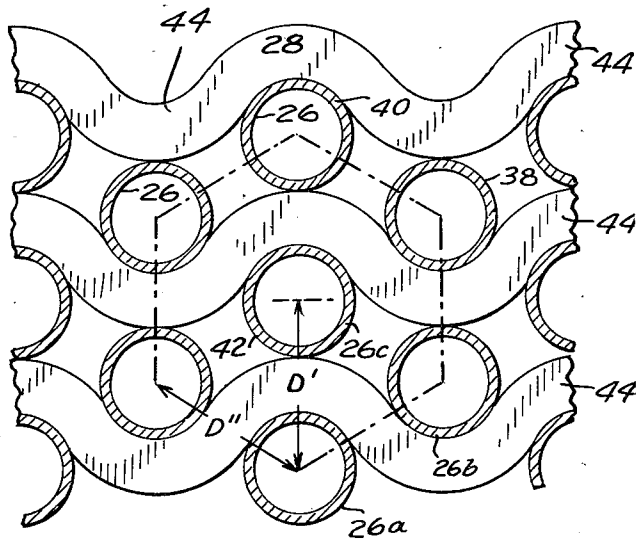


Fig. 5.

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HEAT EXCHANGER TUBE ANTI-VIBRATION STRUCTURE

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9 Claims. (Cl. 165—69)

This invention relates to an anti-vibration structure for tubes of a heat exchanger, and more particularly to an arrangement for preventing vibration in the U-bend portion of tubes of the hair-pin type.

Many vapor generators or heat exchangers today are constructed with bundles of U-shaped tubes either vertically or horizontally disposed. The tubes, which are thin walled and closely spaced may be retained and supported within the exchanger shell by a tube sheet and a plurality of baffles or partitions through which they extend, but even when so held, the closely spaced tubes can vibrate against each other in the bend area of the tubes and become damaged. This can be particularly serious in marine applications and in other installations where the exchanger is associated with or located near types of machinery and where the vibration is severe. Because of design and assembly considerations or requirements on the units, it is generally impossible to locate supporting baffles or partitions in the U-bend area of the tubes. For instance, a prime consideration concerns avoiding structures that will adversely affect the steam flow or flow of the exchange fluid in the heat exchanger shell.

Many structures have been proposed for the purpose of preventing vibration in the bend area of the tubes. These frequently have taken the form of straight rods or spacing strips disposed between layers of tubes and tied together or to the tubes in some manner to prevent them from being dislodged.

Several difficulties are experienced with this type of structure. The spacers prevent vibration of the tubes only in one direction and offer little resistance in other planes of vibration. Further, should the spacing members break free, their configuration often is such that they can slip easily out from between the tubes and cause severe tube damage. Often the structures seriously affect steam flow, and generally the structures are too rigid to permit any differential expansion within the tube bundle.

These and other disadvantages are overcome by the invention, in accordance with which spacing or holding rods are provided having a convoluted or tortuous, wave-like configuration, the thickness of the rods, and their configuration conforming to or being adapted to the spacing and pitch respectively between the tubes or tube rows.

For the purposes of this application, the distance or interval between peaks or corresponding points of the spacing rods shall be defined as the rod pitch. The degree, height or amount of the bend deformation shall be defined as the rod displacement.

More particularly, the invention provides, in a heat exchanger having a cylindrical shell and a tube bundle of U-shaped tubes defining a tube pattern having a triangular or square pitch and disposed within the shell, an anti-vibration structure which includes a plurality of the convoluted spacing rods extending preferably in a direction perpendicular to the planes in which the tubes are disposed, the rods being positioned between layers of tubes at the apices thereof. The pitch and displacement of the rods are such as to conform to the tube pattern whereby the tubes are restrained against movement in the direction lateral to or perpendicular to the planes in which they are disposed, as well as in other directions. An annular holding strap is provided embracing the tube bundle, and located so as to be connected to the ends of the convoluted rods. Preferably, the annular strap consists of parallel members welded to opposite sides of the convoluted rods to restrain the rods against transverse movement should they break free of the straps.

The invention is particularly useful in connection with tubes disposed on or having a triangular pitch. The spacing between layers of tubes then is so little, that the relatively flat spacers of conventional arrangements must be quite thin, and as such, will be deformed easily by the vibrating tubes. When deformed, they offer no resistance to vibration. and tube damage can occur readily.

The anti-vibration structure of the invention is assembled by inserting a first or inner row of tubes of small radius of curvature into the tube sheet and then laying a convoluted spacing rod against the row at the apex thereof. Second and third rows of tubes then are inserted in the tube sheet against the rod and a second spacing rod is laid against it. The entire unit is built up or assembled in this step by step manner, after which the annular holding strap is secured to the spacing rods around the tube bundle.

It will become apparent that, not only are the tubes restrained against vibration, but the rods are securely locked in place by the adjacent layers of tubes, or interlocked with the tubes, so that should the rods break free of the annular straps, they will remain in place. The layers of tubes will prevent them from sliding longitudinally from the tube bundle, and the parallel straps on opposite sides of each rod will prevent any sideways movement.

The invention and advantages thereof will become more apparent on consideration of the following detailed description and accompanying drawings, in which:

FIGURE 1 is a partial, section elevation view of a heat exchanger embodying the concepts of the invention;

FIGURE 2 is a partial section view taken along line 2—2 of FIGURE 1;

FIGURE 3 is an enlarged, elevation view of the anti-vibration structure of FIG. 1 in accordance with the invention;

FIGURE 4 is a further enlarged view of the anti-vibration structure; and

FIGURE 5 is a section view taken along line 5—5 of FIG. 3.

Referring to FIG. 1, there is illustrated a heat exchanger of a type with which the anti-vibration structure of the invention may be used. Essentially, it comprises an elongated vertically oriented pressure vessel 12 of circular cross section containing a cylindrical shroud or baffle 14 defining a vapor generating chamber 16 and an annular downcomer passagway 18. Tube bundles 20, comprised of U-shaped tubes through which a hot primary fluid flows, are disposed within the chamber 16. A riser section 22 is disposed above the shroud 14 and is adapted to convey generated steam to a vapor space (not shown) within the pressure vessel.

The generator structure is illustrated only by way of example, and many types of heat exchangers may usefully embody the concepts of the invention.

The bottom of the generating chamber 16 is defined by a tube sheet 24 extending across the pressure vessel, the tube ends of the tube bundle being disposed in or being retained within the tube sheet. Preferably, the tube pattern in the tube sheet defines a triangular pitch wherein the tubes of adjacent rows are staggered with respect to each other. One of several advantages of the triangular pitch is improved heat transfer for a given heat exchanger volume.

More particularly, referring also to FIG. 2, the tubes are disposed in parallel rows 26*a*, *b*, *c*, etc., successive

rows having progressively graduated radii of curvature 28 in the U-bend portion of the bundle. To define the triangular pitch, the tubes of one row, 26*b* for instance, are positioned in a plane intermediate or between the tubes of adjacent rows 26*a* and *c*. It should be noted that FIG. 2 is only a partial section view showing slightly more than half of the U-bend portion of the tube bundle.

Above the tube sheet, spaced baffles 30 are provided serving to direct the vapor-liquid flow within the generating chamber, and also to support or hold in place the upright tubes, the straight portions of which extend through spaced holes in the baffles. These baffles extend across the steam generating chamber from transverse points of the shroud, and are themselves supported on upright rods 32 between sleeves 34.

Vibration of the tubes may be caused in a number of ways. Machinery associated with or adjacent to the tubes may cause them to vibrate in resonance with the machinery. Turbulence in the steam generating chamber, or a high steam flow rate, may cause vibration.

Because the tubes are bent in the shape of a U, they have a certain degree of rigidity in the plane in which they are bent, or disposed, as well as in their longitudinal direction. The most serious vibration occurs in a direction transverse or perpendicular to the tube plane.

This may be more evident referring to FIG. 2. Above the baffle 36, there is nothing in a conventional unit to restrain the tubes of, for instance, row 38 from vibrating in a direction transverse to the tube plane into the tubes of rows 40 or 42. In the tube plane, the rigidity of the tube itself dampens vibration, although, possibly, even here, the vibration may be so severe as to cause the closely spaced tubes, particularly the larger radius tubes, to distort and vibrate against each other.

This vibration is prevented by disposing convoluted or tortuous wave-like spacing rods 44, FIGS. 2 and 5, between the rows 26 of the tubes at the apices thereof and aligning them with the plane of vibration of the tubes, or perpendicular to the planes in which the tubes are disposed. The spacing rod thickness is adapted to conform to the distance D′ in a vertical direction between alternate rows of tubes and to the spacing D″ in an angular direction between successive rows. The configuration of the rod, or the pitch and displacement dimensions, are adapted to conform to the pitch or arrangement of the tubes.

To assemble the unit, a first row 26*a* of tubes is inserted into the tube sheet, and a convoluted spacing rod is placed at the apex thereof. Second and third rows of tubes then are affixed to the tube sheet and a spacing rod is laid at the apex thereof. This step by step procedure is followed until the entire tube bundle is assembled.

From both FIGS. 2 and 5, it is evident that the spacing rods will effectively restrain the tubes against vibration in a direction transverse to the tube plane. In addition, the rods will effectively restrain the tubes in other planes of vibration, since the rod and tube bundle create a rigid, locked and compact assembly.

The anti-vibration structure is completed by disposing a locating bar 46, FIGS. 1–3, within the bend of the innermost or first row of tubes, 26*a*, and extending an annular strap 48 around the tube bundle encompassing the U-bend portion of the bundle. The strap, consisting of segmented, spaced apart parallel members 50 and 52, FIG. 3, is welded to opposite ends of the locating bar 46, and to each spacing rod on opposite sides and at opposite ends thereof.

In this way, the strap effectively prevents the rods from vibrating or sliding in a transverse direction between the tube rows and becoming displaced from the apices of the rows.

It should now be apparent that the arrangement constitutes a safeguard preventing any dislodgement of the spacing rods. Under severe vibration conditions, the welds between the rods and the encompassing strap may break. The configuration of the rod creates an interlocked structure with the tubes that prevents any sliding or movement in a longitudinal direction, and the parallel members of the encompassing strap prevent movement or sliding in a lateral direction.

At the same time, since the relatively long spacing rods are held at their ends only by the thin, somewhat flexible strap members, the structure permits a differential growth rate in the tube bundle. Specifically, the longer tubes of the bundle will tend to expand at a slightly faster rate than the shorter tubes. Horizontally orienting the spacing bars and tying them only at their ends permits this differential vertical expansion.

Although FIGS. 2 and 5 illustrate a tube pattern having a triangular pitch, the invention is also useful in connection with a square pitch pattern, since here also, retaining the spacing members or rods in place, should they become free or should welds break, is a problem. The spacing rod configuration will prevent them from becoming dislodged.

To secure the anti-vibration structure to the heat exchanger or generator shell, a holding plate 54 is welded to or secured, as shown in FIGS. 3 and 4, to the apical portion 56, FIG. 2 of the structure. This plate is adapted to fit within the riser section 22, FIG. 2, of the generator and to slidably engage members 58 (FIGS. 2 and 3) affixed to the wall of the riser for movement in a perpendicular direction or lengthwise of the tube bundle. This compensates for a differential expansion between the tube bundle and the shroud or baffle 14.

As an alternative arrangement, it may be desired to lock or tie the strap members to the tubes at the apex of the tube bundle. This may be done by welding or otherwise attaching locking nuts to the tubes on opposite sides of the strap members, or by the use of clips or other means.

Although several advantages of the invention have been specified, others should be apparent to those skilled in the art. For instance, the flow of steam in the generator is through the riser section adjacent the U-bend portion of the tube bundle. The anti-vibration structure offers little or no resistance to the steam flow and permits mixing of the steam at the top of the generator rising from opposite sides thereof. Further, the vibration stresses on the structure may be quite severe, and, for design purposes, the arrangement is particularly well adapted to mathematical analysis.

Although the invention has been described with reference to a particular embodiment, many variations will be apparent to those skilled in the art, and the scope of the invention should not be limited except as defined in the following claims.

What is claimed is:

1. In a heat exchanger having a shell and a tube bundle within the shell including a plurality of layers of U-shaped tubes, successive layers of tubes having progressively graduated radii of curvature; an anti-vibration structure comprising a plurality of convoluted spacing rods disposed between the layers of tubes at the apices thereof extending in a direction perpendicular to the tube planes, the rods having a thickness and configuration of crests and troughs conforming to the spacing and pitch of the tubes, the tubes in abutting relationship with certain of said crests and troughs whereby the tubes are restrained against movement in said perpendicular direction, and strap means encompassing the U-bend portion of the tube bundle and connected to ends of said rods.

2. In a heat exchanger having a shell and a tube bundle within the shell including a plurality of layers of U-shaped tubes, the tubes of successive layers defining a triangular pitch and having progressively graduated radii of curvature; an antivibration structure comprising a plurality of convoluted spacing rods disposed between the layers of tubes at the apices thereof extending in a direction perpendicular to the tube planes, the rods having a thickness equal to the spacing between tubes and

a series of crests and troughs having a pitch and displacement conforming to the tube pitch, the tubes in abutting relationship with certain of said crests and troughs, and strap means encompassing the U-bend portion of the tube bundle and connected to the ends of said rods.

3. In a heat exchanger having a shell and a tube bundle within the shell including a plurality of layers of U-shaped tubes, successive layers of tubes having progressively graduated radii of curvature; an anti-vibration structure comprising a plurality of convoluted spacing rods disposed between the layers of tubes at the apices thereof and extending in a direction perpendicular to the tube planes, the rods having a thickness and configuration of crests and troughs equal to and conforming to the spacing and pitch respectively of the tubes, the tubes in abutting relationship with certain of the crests and troughs whereby the tubes are restrained against movement in said perpendicular direction, and strap means encompassing the U-bend portion of the tube bundle and connected to ends of said rods, said strap means comprising parallel members engaging opposite sides of said rods.

4. A heat exchanger having a shell and a tube bundle within the shell including a plurality of layers of U-shaped tubes, successive layers of tubes having progressively graduated radii of curvature, said shell having an outlet coaxial with the tube bundle and adjacent the U-bend portion of the bundle, an antivibration structure comprising a plurality of convoluted spacing rods disposed between the layers of tubes at the apices thereof and extending in a direction perpendicular to the tube planes, the rods having a thickness and configuration of crests and troughs conforming to the spacing and pitch respectively of the tubes, the tubes in abutting relationship with certain of said crests and troughs whereby the tubes are restrained against movement in said perpendicular direction, strap means encompassing the U-bend portion of the tube bundle and connected to ends of said spacing rods, and holding means extending into said opening and secured to said strap means, said holding means being movably secured to the shell opening wall to hold said strap means against lateral movement but to permit movement thereof in the longitudinal direction relative to the tube bundle.

5. A heat exchanger according to claim 4 wherein said strap means comprises parallel members engaging opposite sides of said spacing rods and restraining the rods against lateral movement.

6. A heat exchanger having a cylindrical vertically oriented shell defining a vapor generating chamber, a riser section at the upper end of the shell and a tube sheet at the bottom end of the shell, a tube bundle within said chamber having a plurality of layers of U-shaped tubes, successive layers of tubes having progressively graduated radii of curvature, said layers of tubes being disposed in said tube sheet to define a tube pattern having a triangular pitch; an anti-vibration structure comprising a plurality of convoluted spacing rods disposed between the layers of tubes at the apices thereof and extending in a direction perpendicular to the planes in which the tubes are disposed, the rods having a thickness and configuration of crests and troughs equal to and conforming to the spacing between tubes and pitch of the tubes respectively, the tubes in abutting relationship with certain of the crests and troughs, strap means encompassing the U-bend portion of the tube bundle and connected to the ends of the spacing rods, the strap means comprising parallel members engaging opposite sides of the spacing rods, and holding means extending from the strap means into said riser section and movably secured to the walls thereof to restrain the strap means and spacing rods from lateral movement but to permit movement in a longitudinal direction relative to the tube bundle.

7. In a heat exchanger having a shell and a tube bundle contained within the shell including a plurality of layers of U-shaped tubes disposed in parallel planes successive layers of tubes having progressively graduated radii of curvature, an anti-vibration structure comprising a plurality of convoluted spacing rods disposed between the layers of tubes at the apices thereof in a direction substantially perpendicular to the tube planes, the rods having a thickness and configuration of crests and troughs conforming to the spacing and pitch of the tubes, the tubes in abutting relationship with certain of the crests and troughs whereby the tubes are restrained against movement in said perpendicular direction, and strap means encompassing the U-bend portion of the tube bundle and connected to ends of said rods.

8. A heat exchanger according to claim 7 wherein said spacing rods are disposed in a plane oriented at a substantially perpendicular angle relative to the tube planes.

9. A heat exchanger according to claim 7 wherein said spacing rods are disposed in a plane aligned with the apices of the tubes and which is perpendicular to the parallel planes in which the tubes are disposed.

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