Jan. 12, 1960 K. A. GARDNER 2,920,874

STEAM GENERATOR CONSTRUCTION

Filed June 22, 1955 3 Sheets-Sheet 1

Fig. 1

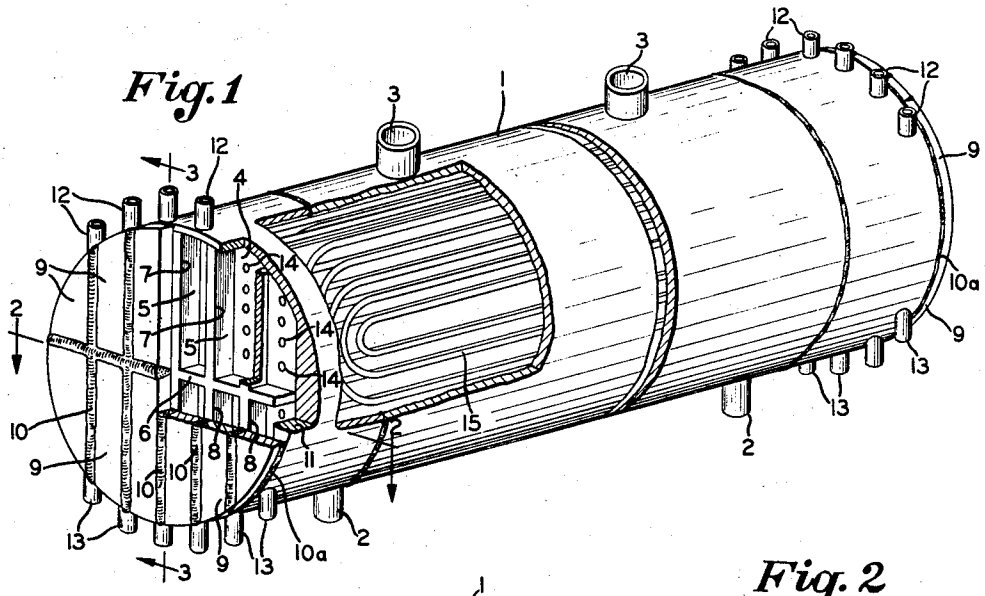
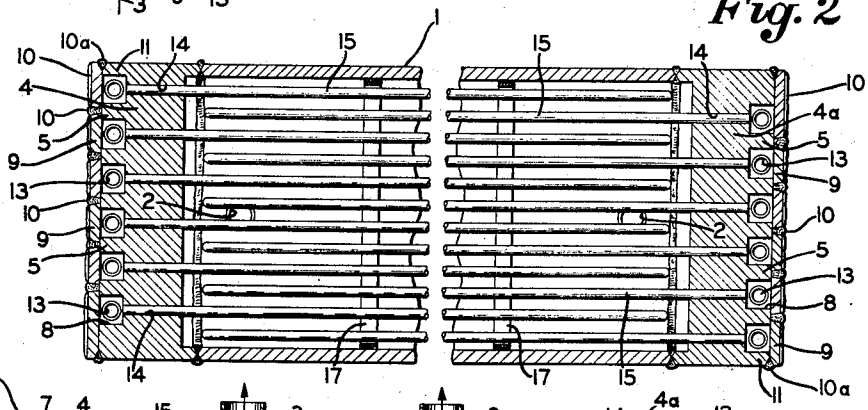


Fig. 2



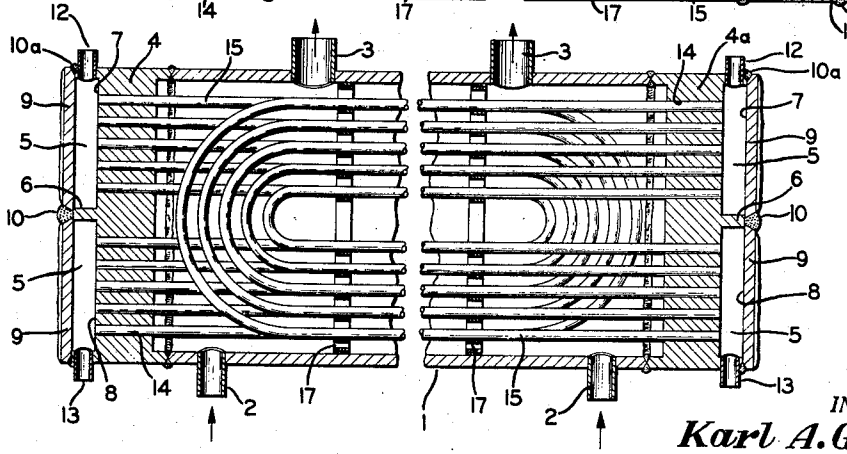


Fig. 3

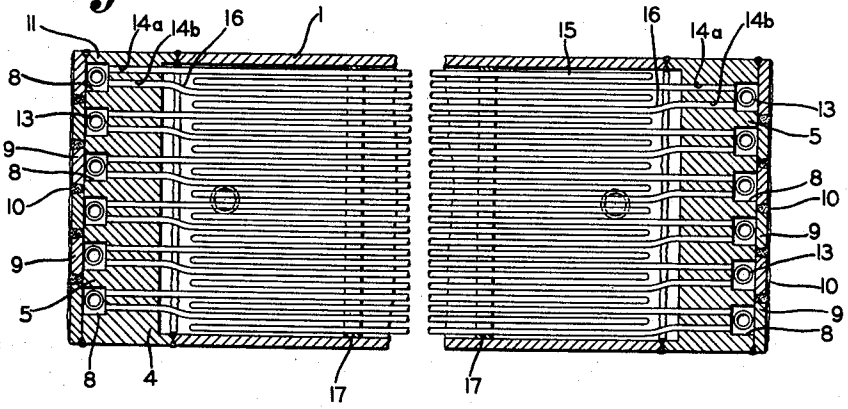
INVENTOR.
Karl A. Gardner
BY
Frease & Bishop
ATTORNEYS

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STEAM GENERATOR CONSTRUCTION

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Fig. 4



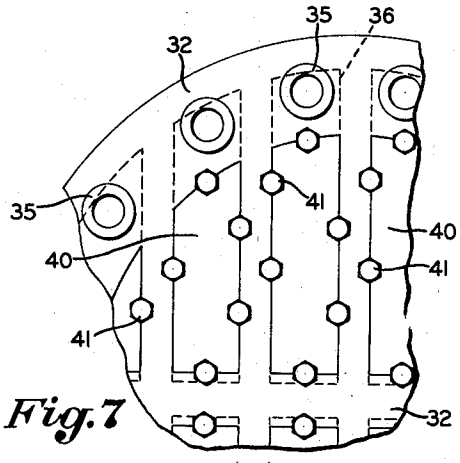


Fig. 7

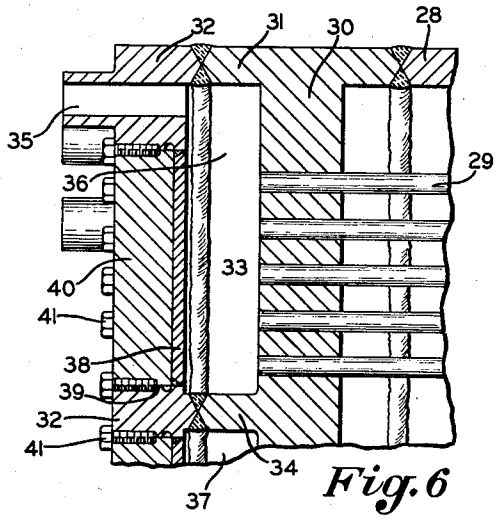


Fig. 6

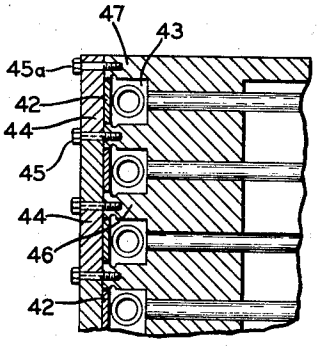


Fig. 8

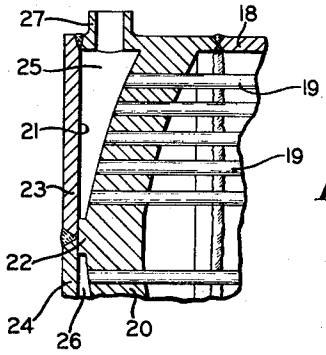


Fig. 5

INVENTOR.

Karl A. Gardner

BY *Frease & Bishop*

ATTORNEYS

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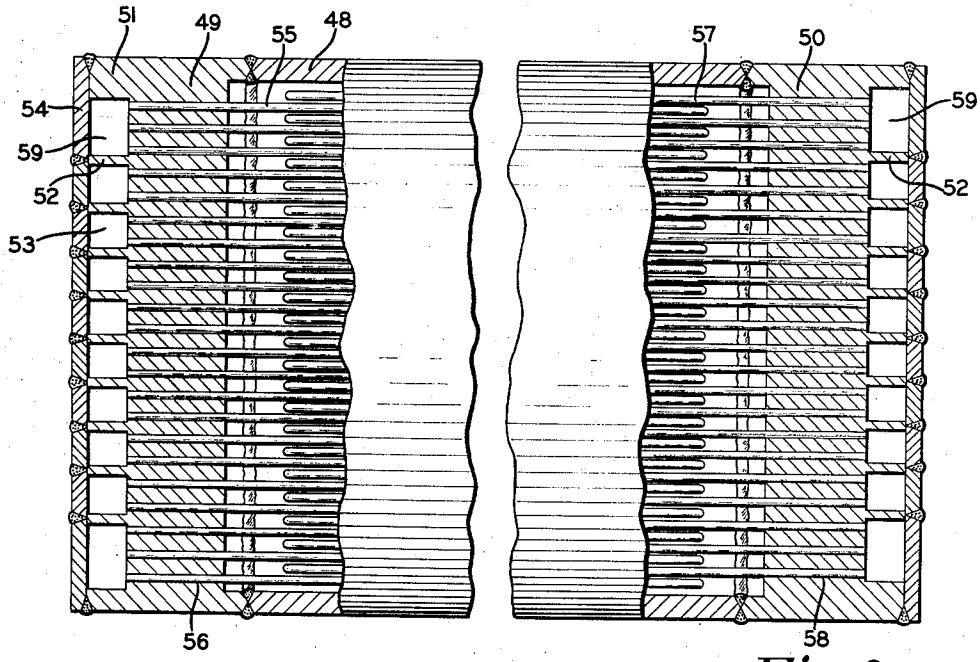


Fig. 9

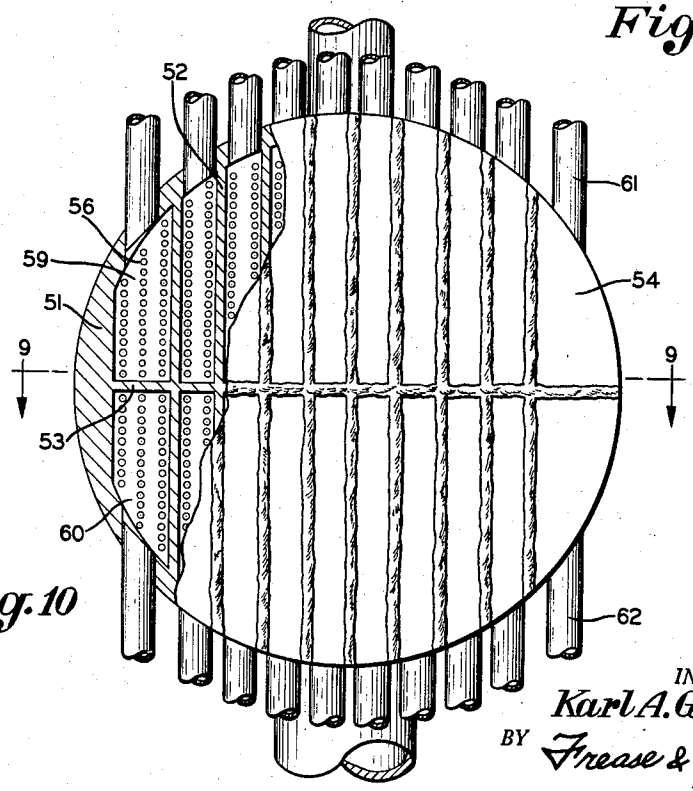


Fig. 10

INVENTOR.
Karl A. Gardner
BY Frease & Bishop
ATTORNEYS

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2,920,874

STEAM GENERATOR CONSTRUCTION

Karl A. Gardner, Canton, Ohio, assignor to The Griscom-Russell Company, Massillon, Ohio, a corporation of Delaware

Application June 22, 1955, Serial No. 517,125

3 Claims. (Cl. 257—239)

This invention relates to heat exchangers and it pertains more particularly to a steam generator heat exchanger having interleaved U-tube heat exchange tubes extending from opposite heads at either end of the heat exchanger.

In any heat exchanger it is desirable to keep the size of the shell and tube fluid heads as small as possible, in order to keep the weight and the cost of the parts which do not contribute to heat transfer, at a minimum. In certain applications there are further reasons for reducing the size of the equipment, such as equipment within the shield area of a nuclear reactor, or an aircraft, or in seagoing vessels. In such instances, the size and mass of other equipment external to the heat exchanger may be determined by factors preventing reduction of size or mass so that any minimizing of the size and mass of an associated heat exchanger may constitute the only important reduction in size or mass of the equipment as a whole that can be made.

In many processes using heat exchangers the process can continue at decreased efficiency with the heat exchanger entirely out of the circuit in the event of leakage or failure of the heat exchanger. In other processes this is not possible and a failure of the heat exchanger will interrupt the entire process unless a standby heat exchanger is provided for such emergency. Where, however, a heat exchanger is a major item of equipment, considerations of economy do not permit the provision of a standby heat exchanger for emergency use. Likewise, where space is at a premium, such as in sea-going vessels or in a shielded area, the provision of a standby heat exchanger for emergency purposes is not practicable.

One alternative to the provision of a standby heat exchanger for emergency use is the compartmentation of the heat exchanger fluid streams directed through the heat exchanger. In many cases, compartmentation of fluid streams may make it possible to continue operation of the process in event of a local failure by detecting the location of the failure and shutting down the particular fluid stream affected while continuing all others in operation. In effect, compartmentation amounts to a multiplicity of standby heat exchangers in one major piece of apparatus, no one of which is capable of handling more than a small part of the total duty.

Thus, a compartmentalized heat exchanger is an answer to considerations of space and weight limitations and a process of critical nature which does not permit the continuation of the process with the heat exchanger entirely out of the circuit. Both of the foregoing considerations of space and weight limitation and the critical nature of the process apply to the steam generator of a power plant, and particularly to a steam generator for a mobile power plant in a ship or submarine.

The steam generator construction of the present invention satisfies the requirements of space and weight limitation and critical processing. Ordinarily a compartmentalized heat exchanger occupies a certain minimum

amount of space for a given application. Heretofore, compartmentation has been achieved with the sacrifice of space within the heat exchanger due to partitions between each compartment with which a given set of heat exchange tubes communicates; or with an increase in diameter of the unit to accommodate compartment partitions or connections. The present invention overcomes these disadvantages and improves the overall design of conventional compartmentalized heat exchangers and at the same time uses most efficiently the space within a heat exchanger of minimum lateral dimension.

It is a general object of this invention to provide a heat exchanger having a size which is as small as possible in order to not only minimize the space occupied thereby and the overall weight of the heat exchanger but also to minimize the cost of parts which do not contribute directly to heat transfer.

It is another object of this invention to provide a compartmentalized heat exchanger having a reduced size in order to conserve space for other purposes.

It is another object of this invention to provide a compartmentalized heat exchanger which may be operated at reduced efficiency in the event of failure of a particular part thereof without interrupting operation of the entire process in which the heat exchanger is used.

Another object of this invention is to provide a heat exchanger which may be used in the operation of processes that are critical in nature and which may not be continuously operated without a heat exchanger, such as a steam generator.

Finally, it is an object of this invention to provide an improved heat exchanger which incorporates the foregoing desiderata in an inexpensive manner and with simplified maintenance and operation.

These and other objects and advantages apparent to those skilled in the art from the following description and claims may be obtained, the stated results achieved and described difficulties overcome by the discoveries, principles, apparatus, parts, combinations, subcombinations and elements which comprise the present invention, the nature of which is set forth in the following statement, preferred embodiments of which—illustrative of the best modes in which applicant has contemplated applying the principles—are set forth in the following description, and which are particularly and distinctly pointed out and set forth in the appended claims forming part hereof.

Generally, the nature of the improved apparatus of the present invention may be stated in general terms as including, a cylindrical shell, tube sheets at opposite ends thereof, the sides of each tube sheet remote from the shell having a number of parallel compartments separated by partition lands, at least one partition extending centrally across the tube sheet perpendicular to the remaining partitions and providing parallel compartments on either side of the central partition, at least one row of the tube-receiving openings communicating with each compartment, at least one row of openings in one tube sheet being aligned with the lands on the other tube sheet, a U-shaped tube extending from each opening in a compartment on one side of said central partition to an opening in a corresponding compartment on the other side of said central partition, the tubes extending from the openings of a particular compartment being disposed in the same plane and said plane being offset from the plane of tubes extending from openings in the corresponding compartment in the opposite tube sheet.

In the accompanying drawings which are illustrative of preferred embodiments of the invention, by way of example, and in which similar numerals refer to similar parts thereof:

Fig. 1 is a perspective, diagrammatic view of one embodiment of the present invention with parts broken away;

Fig. 2 is a horizontal sectional view taken on the line 2—2 of Fig. 1;

Fig. 3 is a vertical sectional view taken on line 3—3 of Fig. 1;

Fig. 4 is a horizontal sectional view of another embodiment having two rows of heat exchange tubes extending from each compartment;

Fig. 5 is a fragmentary vertical sectional view of another embodiment of the invention showing a modified form of construction;

Fig. 6 is a fragmentary vertical sectional view of a further modified form construction having ports communicating with the compartments extending in an axial direction from the end of the head;

Fig. 7 is a fragmentary end view of the construction, shown in Fig. 6;

Fig. 8 is a fragmentary vertical sectional view of a further modified form of construction;

Fig. 9 is a fragmentary plan sectional view on the line 9—9, Fig. 10 of a further modified form of construction; and

Fig. 10 is an end view with parts broken away of the construction shown in Fig. 9.

The heat exchanger shown in Figs. 1, 2 and 3 includes a cylindrical shell **1**, provided with inlet ports **2** and outlet ports **3** and tube sheets **4** and **4***a* at either end of the shell. A plurality of dividers, lands or partition walls **5**, spaced apart and parallel with each other, are provided on the outer side of each tube sheet **4** and **4***a*, shown in Figs. 1, 2 and 3 as extending preferably vertically. A central partition member **6** is also provided on the outer side of tube sheet **4** and located perpendicularly with respect to the spaced parallel partition members **5** and forming therewith a series of upper compartments **7** and lower compartments **8** (Figs. 1 and 3). Each compartment **7** or **8** forms a head compartment for one end of a group of U-tubes **15** to be later described.

The outer end of each compartment **7** or **8** is closed by a cover plate **9**, which may be welded at **10** to the partition members **5** and **6** and at **10***a* to the circumscribing cylindrical wall **11** forming a projection of the shell beyond each tube sheet **4** and **4***a*. Thus, each cover plate **9** has a generally trapezoidal shape with one end welded to the central partition member **6**, one or more sides welded to the spaced parallel partition walls **5** and an arcuate end or an arcuate side and end welded to the cylindrical wall **11**, thereby forming a fluid-tight closure for each compartment **7** and **8**.

Tube inlet ports **12** communicate through the cylindrical head extension wall **11** with each upper compartment **7**; and tube outlet ports **13** communicate through cylindrical wall **11** with the lower compartments **8**. The upper inlet ports **12** at each end of the heat exchanger are preferably connected together by a manifold (not shown) and the inlet port manifolds in turn are preferably connected together and communicate with a main coolant inlet (not shown). Similarly the outlet ports **13** may be connected together by suitable manifolds at each end of the heat exchanger, which manifolds may communicate with a common coolant outlet (not shown).

A plurality of tube-receiving openings **14** are formed in each tube sheet **4** and **4***a*. The tube openings **14** as shown in Figs. 1, 2 and 3 may be aligned in a single row in each compartment **7** or **8**. A series of U-tubes **15** of usual construction are located within the shell **1**. One group of U-tubes are nested in a vertical plane one within another with the upper ends of each U-tube of the group secured in any usual fluid-tight manner within the openings **14** communicating with the upper compartment **7** of the tube sheet **4**. The other ends of the U-tubes in such group are secured in the openings **14** communicating with the corresponding lower compartment **8** as best shown in Figs. 1 and 3. Similarly, other groups of U-tubes are secured in openings **14** in the tube sheet **4***a* communicating with the upper and lower compartments **7** and **8** of the tube sheet **4***a*. As shown in Fig. 2, the spaced parallel tube sheet partition walls **5** in the tube sheet **4** are offset laterally with respect to the spaced parallel partition walls **5** in the tube sheet **4***a* so that planes passing through the center lines of the partition walls **5** in tube sheet **4** lie generally in the planes of the center lines of each group of U-tubes **15** connected to tube sheet **4***a* and vice versa. In this manner, the groups of U-tubes connected with the tube sheets **4** and **4***a* are interleaved without loss of space on the face of the tube sheets because of the provision of the partition ribs or members **5**, as would be the case if all U-tubes entered a single tube sheet provided with partition ribs for obtaining compartmentation.

For clarity of illustration, the tubes, tube spacing, tube size, etc., are shown somewhat diagrammatically in Figs. 1, 2 and 3, it being understood that the tubes may be of larger relative diameter than shown and more closely spaced to provide a greater number of tubes so as to locate a maximum amount of tube surface within the shell **1**.

In operation, coolant flowing from the main coolant inlet will enter the tube inlet ports **12** at each end of the heat exchanger and flow to the upper compartments **7** of the tube sheets **4** and **4***a*, thence through the U-tubes **15**, thence to the lower compartments **8** in each tube sheet **4** and **4***a*, thence out through the tube outlet ports **13** to the main coolant outlet. At the same time, shell fluid may enter the shell inlet ports **2** and pass within the shell around the surfaces of the U-tubes **15** and out through the shell outlet ports **3** in performing the heat exchange operation.

The arrangement of the improved construction by which our nested group of tubes communicates with its own upper and lower head compartments **7** and **8**, which particular compartments **7** and **8** are separated from all other compartments **7** and **8** in each tube sheet **4** and **4***a* provides compartmentation for the tubes so that in event of failure of any particular tube, it is only necessary to cut off fluid flow to the group of tubes and compartments **7** and **8** with which the failed tube communicates, permitting continued operation of the heat exchanger. Meanwhile, the failed tube may be repaired by opening up the cover plates **9** on the compartments **7** and **8** which communicate with the tube failure.

At the same time there has been no sacrifice in space, or substantial increase in weight by achieving compartmentation because of the interleaved arrangement of the groups of tubes and the connection of one series of tube groups with one tube sheet **4** and the connection of the other series of groups of tubes with the tube sheet **4***a*. As indicated, this compartmentation without sacrificing space is achieved by locating the compartments **7** and **8** and the spaced parallel partition walls **5** forming the same in one tube sheet **4** offset with respect to the compartments **7** and **8** and partition walls **5** in the tube sheet **4***a* at the other end of the heat exchanger, so that the U-bends of one group of nested U-tubes connected with one tube sheet are opposite a partition wall **5** in the other tube sheet. In this manner, a compact tube bundle with normal concentration of tubes throughout most of the length of the heat exchanger is provided.

Fig. 4 illustrates a modified form of construction in which two groups of nested tubes communicate with each upper compartment **7** and corresponding lower compartment **8**. In this modified arrangement, two rows of tube openings **14***a* and **14***b* are provided in each compartment **7** and **8** with the centers of the tubes in one row of the tube openings **14***a* located in a plane parallel to the tube openings **14***b* in the other row. In order to accommodate interleaving of the groups of tubes in the construction

shown in Fig. 4, the group of tubes connected with the tube openings 14*a* all lie in the same plane, but the groups of tubes connected with the openings 14*b* are bent at 16 to laterally offset the plane of the tube portions within the shell 1 of any group of nested tubes from the plane of the tube openings 14*b* therefor. Thus a space is provided between the pair of two groups of tubes communicating with one set of upper and lower compartments 7 and 8 in which a group of tubes connected with the opposite tube sheet may be interleaved.

In this manner more than one group of tubes 15 per compartment may be used without increasing the circumferential size of the head portions of the heat exchanger while at the same time achieving compartmentation.

Tube spacer means 17 may be provided in each of the heat exchangers shown in Figs. 1, 2, 3 and 4 in the usual manner within the shell 1 to maintain the proper or desired spacing between tubes and groups of tubes nested and interleaved within the shell 1.

A modified form of construction is shown in Fig. 5 and includes a shell 18, U-tubes 19, a tube sheet member 20, spaced parallel vertical partition walls 21, a central partition wall or member 22 and upper and lower cover plates 23 and 24 for the upper and lower compartments 25 and 26. The compartments 25 and 26 may be provided with tube inlet and outlet ports similar to those in the heat exchanger illustrated in Figs. 1, 2 and 3, a tube inlet port 27 being indicated in Fig. 5.

In the construction shown in Fig. 5, the tube sheet 20 is curved in cross section in any direction so that the upper and lower compartments 25 and 26 formed between the tube sheet 20 and cover plates 23 and 24 and the partition members 21 and 22 define chambers which are generally triangular in cross section as shown in Fig. 5.

A further modified form of construction is illustrated in Figs. 6 and 7 including a shell member 28, U-tubes 29, a tube sheet 30, a shell extension wall portion 31, and a head wall 32. Vertical partition walls 33 and a central partition wall 34 extend between the tube sheet 30 and head wall 32 generally in the same manner as the partition walls 5 and 6 in the construction shown in Figs. 1, 2 and 3. However, the modified construction enables the tube inlet and outlet ports, such as the tube inlet port 35 shown in Fig. 6, to extend in a direction axially of the heat exchanger thereby conserving space laterally of the heat exchanger where the conditions of installation require such space conservation.

The upper compartments 36 and lower compartments 37 formed between the tube sheet 30 and head wall 32 by the partition walls 33 and 34 may be individually closed by welding a diaphragm plate 38 at the inner end of the opening 39 communicating with each of the upper and lower compartments 36 and 37 to provide a liquid-tight closure for the compartments. Back-up plates 40 may be mounted within the openings 39 and secured therein by bolts 41 which may be threaded into threaded openings each lying half in the head wall 32 and along the perimeter of the opening 39 and half in the outer surface of each back-up plate 40. The arrangement of the back-up plates 40 supports the loads imparted to the diaphragm plates 38 from the pressure contained within each compartment 36 and 37 and furnish a means of obtaining quicker access to the compartments for repairs in event of tube failure.

In the construction shown in Figs. 6 and 7, the bolts 41 and back-up plate 40 for any particular compartment may be quickly removed and the diaphragm plate 38 cut out to gain access to any particular compartment. A new diaphragm plate may be welded in place after the repairs are made. Such repairs are quicker than those required for cutting out and removing any of the cover plates 9 illustrated in Figs. 1, 2 and 3.

The construction illustrated in Fig. 8 is a modification of that shown in Figs. 1, 2 and 3 and uses diaphragms and back-up plates for each upper and lower compartment rather than the welded cover plates 9 as shown in Figs. 1, 2 and 3. In Fig. 8, individual diaphragm plates 42 may be welded in place, to close in a liquid-tight manner each of the upper or lower compartments such as the lower compartments 43, in a manner similar to the construction shown in Fig. 6. The back-up plates 44 may be bolted as at 45 and 45*a* to the vertical partition walls 46 and the shell extension wall 47. The bolts 45*a* secure the outer edges of the outer back-up plates to the shell extension wall 47, and the bolts 45 are threaded into half-threaded openings provided in the abutted edges of adjacent back-up plates and secure the same to a common partition wall.

A still further modified form of construction is shown in Figs. 9 and 10 which is similar to that shown in Figs. 1, 2 and 3 excepting that a much larger number of tubes are shown, and two groups of tubes communicate with most of the compartments while three rows of tubes communicate with the compartments at either side of the heat exchanger.

The construction in Figs. 9 and 10 includes a shell 48, tube sheets 49 and 50, a shell extension wall 51, spaced vertical partition walls 52, a central partition wall 53 and cover plates 54 welded to the partition walls 52 and 53 and the circumscribing shell extension wall 51.

A series of groups of nested tubes 55 are connected to openings 56 in the tube sheet 49, and another series of groups of tubes 57 are connected to tube openings 58 in the tube sheet 50. The tubes 55 and 56 communicate as indicated with the various upper and lower compartments 59 and 60 formed by the partition walls 52 and 53, and these compartments may be provided with tube inlet ports 61 and tube outlet ports 62.

With the arrangement shown in Figs. 9 and 10, two groups of tubes communicate with each set of upper and lower compartments 59 and 60 except the outermost compartments where three groups of tubes communicate with such compartments. This arrangement permits interleaving of the groups of tubes because one of the groups of tubes communicating with one set of compartments adjacent the tube sheet 49 lies in the plane of a partition wall 52 extending from tube sheet 50; and one of the groups of tubes communicating with the compartments adjacent tube sheet 50 lies in the plane of a partition wall 52 extending from tube sheet 49. In this manner there is no loss of space on the face of the tube sheets in providing the partition walls to obtain compartmentation.

In each of the embodiments of the invention shown, compartmentation in the heat exchanger is achieved on the face of the tube sheet without sacrificing space for the partitions forming the compartments which would normally occur if all the U-tubes entered a single tube sheet. Thus, a compact bundle of tubes may be provided within the shell with normal tube concentration throughout most of the length of the shell. As shown, the compartments may be provided with any one of a number of types of closure or cover means to contain the fluid pressure existing in the compartments in a liquid-tight manner.

Other advantages achieved by the improved construction are that compartmentation is obtained without sacrifice of space and yet the tube openings in the tube sheets may be drilled in the normal way on the face of a flat disc; and the U-tubes used are only formed with simple bends in a usual manner with many U-tubes in the various tube groups identical in size and shape of U-bend.

The only disadvantage inherent in the improved construction is that the unit cannot be operated in a vertical position if complete drainage of the tubes is essential and must under such conditions always be located in a horizontal position. However, this disadvantage is far outweighed by the provision of compartmentation in a compact space for a horizontally installed heat exchanger such as a steam generator.

Accordingly, the present invention provides a new construction of heat exchanger in which compartmentation is provided without increasing space requirements for and weight of heat exchangers which must be continuously operated without complete shutdown in event of tube failure and without requiring stand-by units.

In the foregoing description, certain terms have been used for brevity, clearness and understanding, but no unnecessary limitations are to be implied therefrom beyond the requirements of the prior art, because such terms are used for descriptive purposes and are intended to be broadly construed.

Moreover, the embodiments of the improved construction illustrated and described herein are by way of example, and the scope of the present invention is not limited to the exact details of construction shown.

Having now described the features, construction and principles of the invention, the characteristics of the new steam generator construction, and the advantageous, new and useful results provided; the new and useful discoveries, principles, parts, combinations, sub-combinations, structures and arrangements, and mechanical equivalents obvious to those skilled in the art, are set forth in the appended claims.

I claim:

1. Heat exchanger construction including a shell, a tube sheet at each end of the shell; the outer face of each tube sheet being provided with spaced generally vertically extending partition walls, a center laterally extending partition wall and a circumscribing shell wall extension; said partition walls and extension being integral with the tube sheet and forming a series of upper and corresponding lower compartments, each compartment having a separate outer cover plate secured to the partition walls and to the shell wall extension forming the compartment, there being at least one row of tube openings formed in each tube sheet communicating with each compartment, at least one row of tube openings communicating with each compartment in one tube sheet being aligned with a vertical partition wall in the other tube sheet, a group of nested U-tubes connected at one end to each row of tube openings communicating with each upper compartment and connected at the other end to the corresponding row of tube openings communicating with the corresponding lower compartment, the nested U-tubes in any group extending from one tube sheet being disposed in the same plane, said plane being offset from the plane of a corresponding group of U-tubes extending from the other tube sheet, and each group of nested U-tubes on one tube sheet extending to a location near the opposite tube sheet and between two groups of nested U-tubes extending from said other tube sheet.

2. Heat exchanger construction including a shell, tube sheets at opposite ends of the shell, walls integral with the tube sheet and forming a plurality of inlet and outlet head compartments on each tube sheet, the inlet compartments on each tube sheet being located side by side and parallel with each other, the outlet compartments on said tube sheet being similarly located and aligned with corresponding inlet compartments, each compartment having a separate outer cover plate secured to the walls forming the compartment, there being at least one row of tube openings formed in each tube sheet communicating with each compartment, the rows of openings in one tube sheet being offset with respect to similar rows of openings in the other tube sheet, a plurality of nested groups of U-tubes having inlet and outlet ends within the shell, the inlet ends of one group of U-tubes being connected to aligned openings communicating with an inlet compartment associated with one tube sheet, the outlet ends of said one group of U-tubes being connected to aligned openings communicating with the corresponding outlet compartment associated with said one tube sheet, there being other groups of U-tubes similarly connected to the remaining inlet and outlet compartments associated with both tube sheets, the nested U-tubes of any group extending from one tube sheet being disposed in a plane parallel and adjacent to a similar group of nested U-tubes extending from the other tube sheet, and each group of nested U-tubes on one tube sheet extending to a location near the opposite tube sheet and between two groups of nested U-tubes extending from said other tube sheet.

3. Heat exchanger construction including a shell, a tube sheet at each end of the shell, partition walls extending from the outer face of each tube sheet including spaced parallel vertical partition walls and a central partition wall perpendicular to the spaced parallel partition walls and forming parallel upper and lower compartments on either side of the central partition wall, said partition walls being integral with the tube sheet, head closure means for each compartment welded to the partition walls, inlet means communicating with each upper compartment, outlet means communicating with each lower compartment, there being at least one row of tube openings formed in the tube sheet communicating with each compartment, at least one row of openings in one tube sheet communicating with each compartment being aligned with a vertical partition wall extending from the other tube sheet, a U-tube extending from each opening in a tube sheet communicating with an upper compartment to an opening in said tube sheet communicating with a corresponding lower compartment, the U-tubes extending from the openings of a particular row communicating with one compartment being disposed in the same plane, said plane being offset from the plane of tubes extending from openings communicating with a corresponding compartment in the other tube sheet, and each group of nested U-tubes on one tube sheet extending to a location near the opposite tube sheet and between two groups of nested U-tubes extending from said other tube sheet.

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