United States Patent [19]

Mangus

[11] **3,907,026**

[45] **Sept. 23, 1975**

[54] **DOUBLE TUBE HEAT EXCHANGER**

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[73] Assignee: **Westinghouse Electric Corporation,** Pittsburgh, Pa.

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[21] Appl. No.: **390,282**

[52] **U.S. Cl.** **165/70;** 165/104; 165/134; 165/135; 165/142

[51] **Int. Cl.** **F28f 11/00**

[58] **Field of Search** 165/70, 142

[56] **References Cited**

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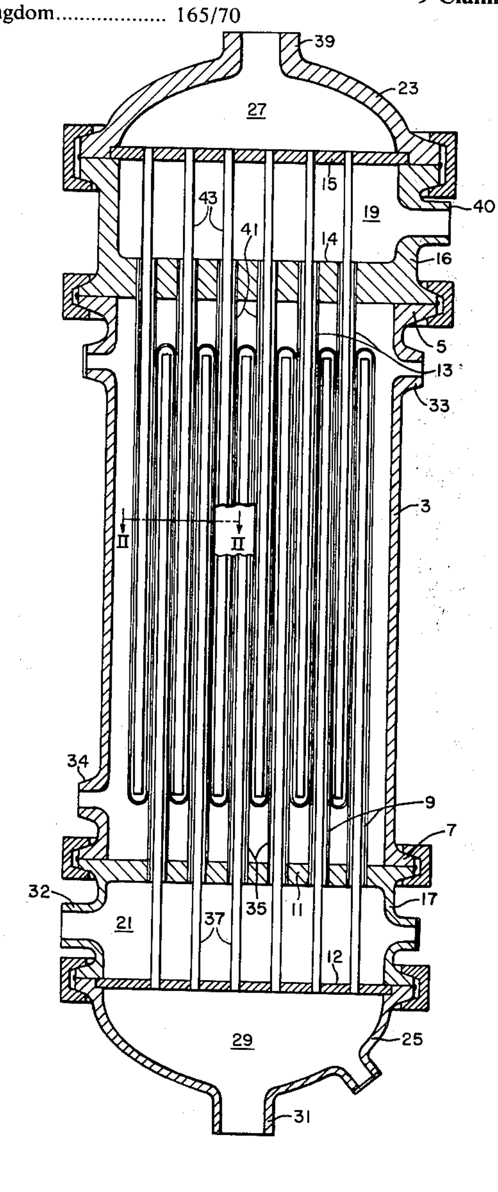
Assistant Examiner—S. J. Richter
Attorney, Agent, or Firm—F. J. Baehr, Jr.

[57] **ABSTRACT**

A heat exchanger wherein a primary fluid flows through one group of tubes and transfers heat to a secondary fluid flowing through another group of tubes. The tubes of one group are interdigitated with the tubes of the other group and a heat transfer material is interposed to generally fill the voids between the tubes. Pressurized inert gas is also supplied to the heat exchanger to fill the voids remaining between the heat transfer material and the tubes. A shell forms a closure around the tubes, heat transfer material and inert gas to provide an intermediary chamber into which primary and secondary fluid can flow, if a tube in either group leaks.

9 Claims, 15 Drawing Figures



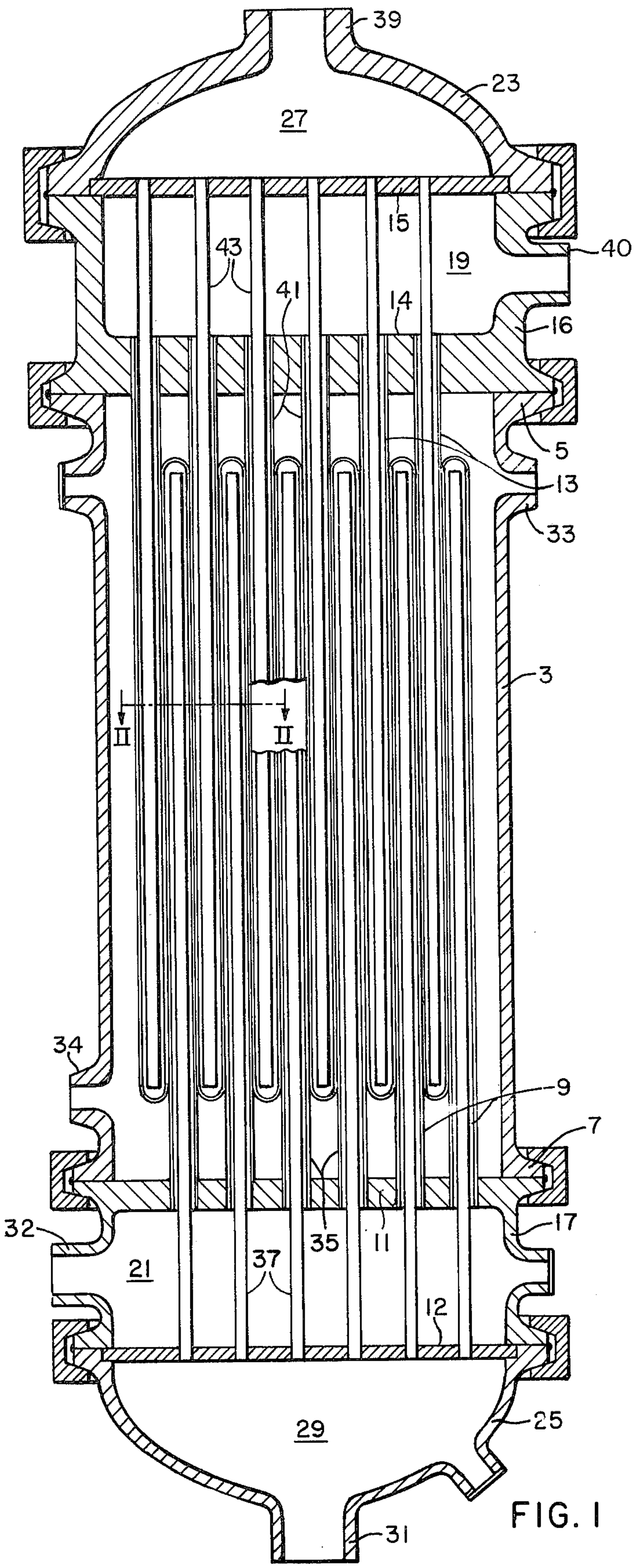

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FIG. 1

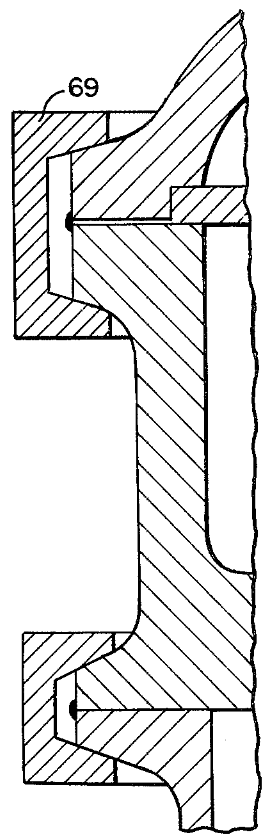
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FIG. 14

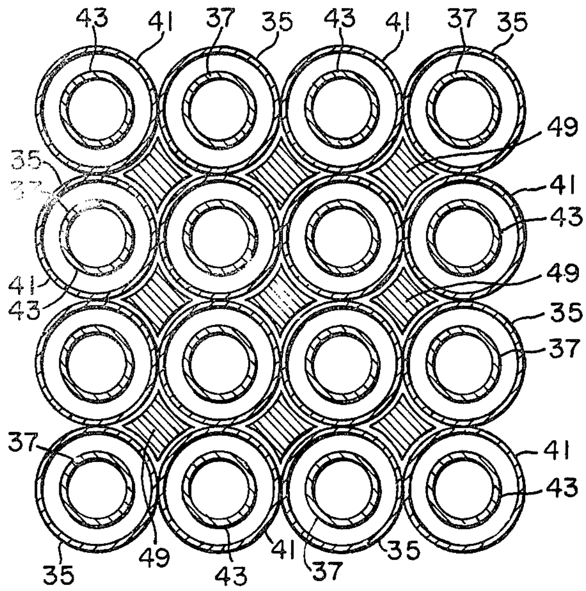
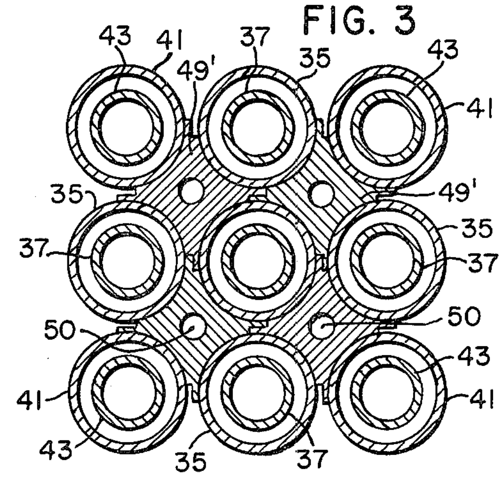


FIG. 2

FIG. 3



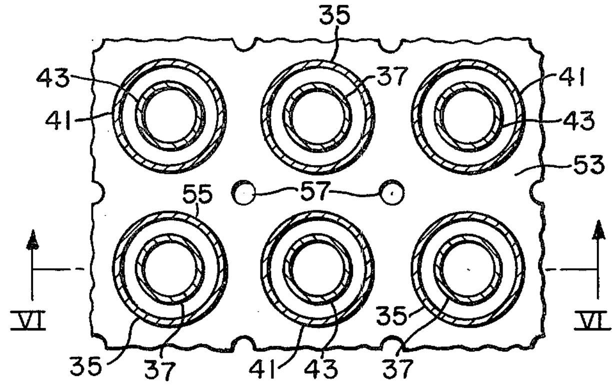


FIG. 5

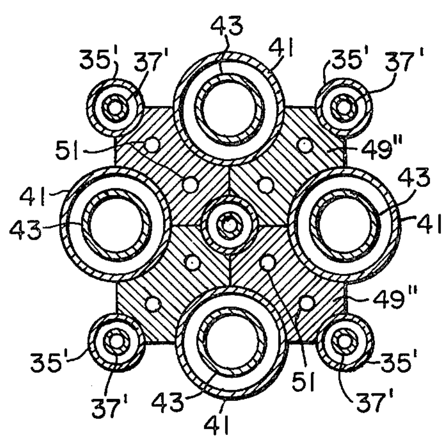


FIG. 4

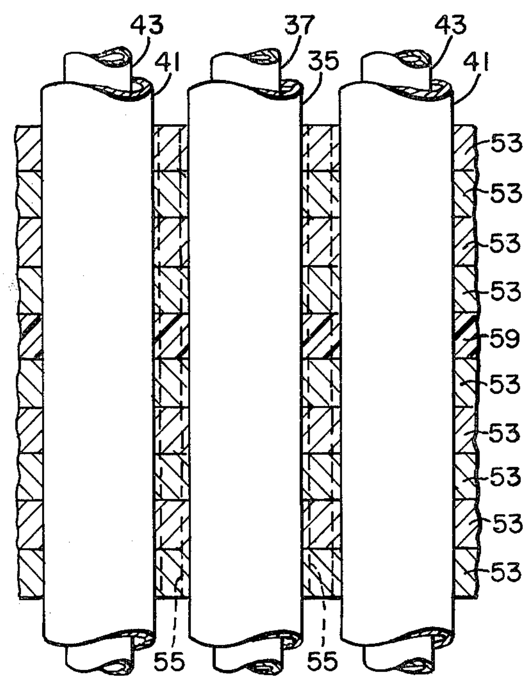


FIG. 6

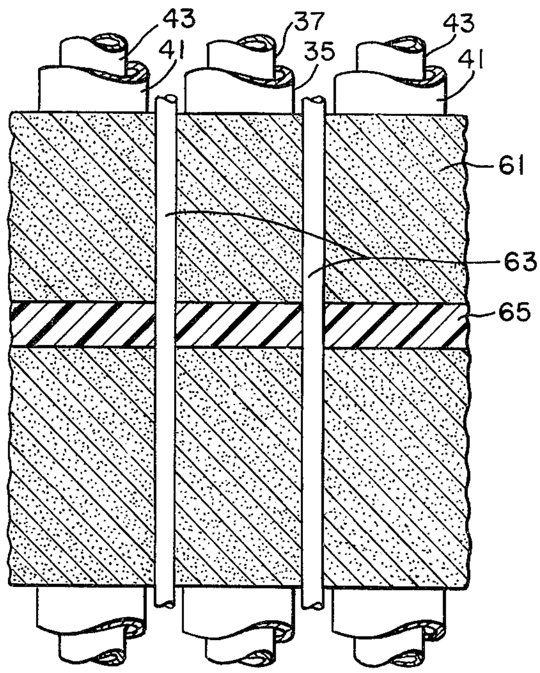


FIG. 7

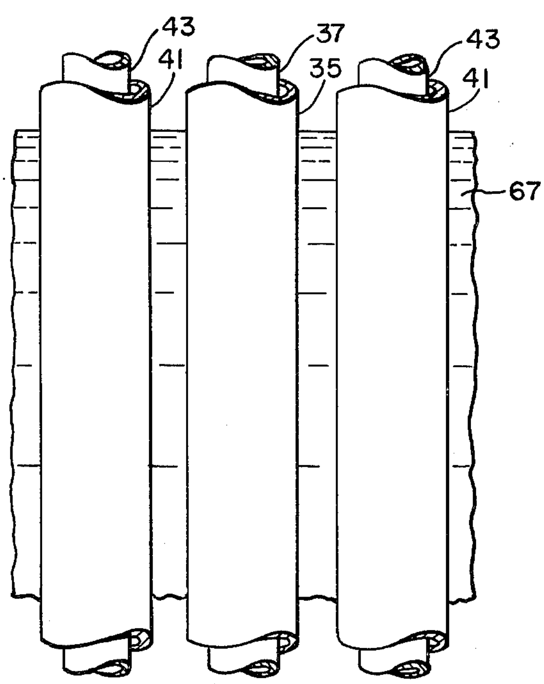


FIG. 8

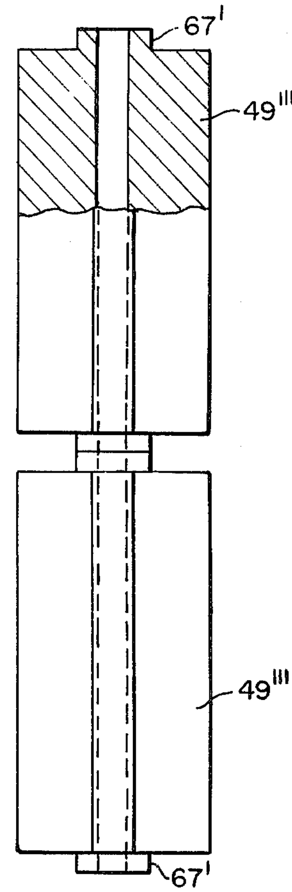


FIG. 9

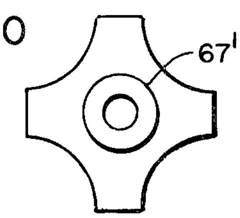


FIG. 10

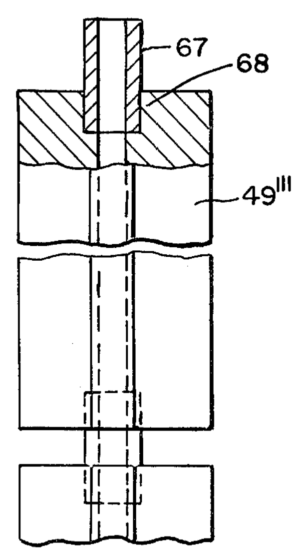


FIG. 11

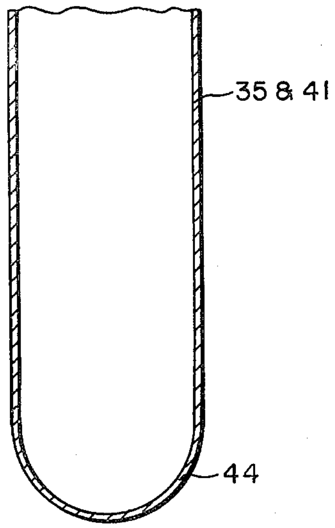


FIG. 12

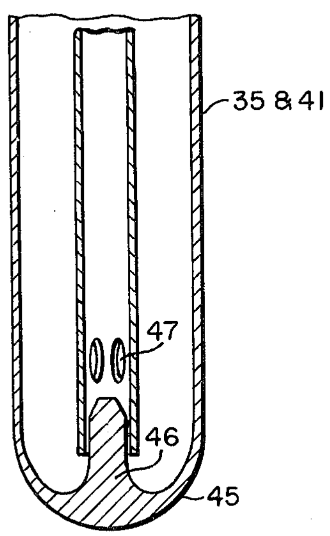


FIG. 13

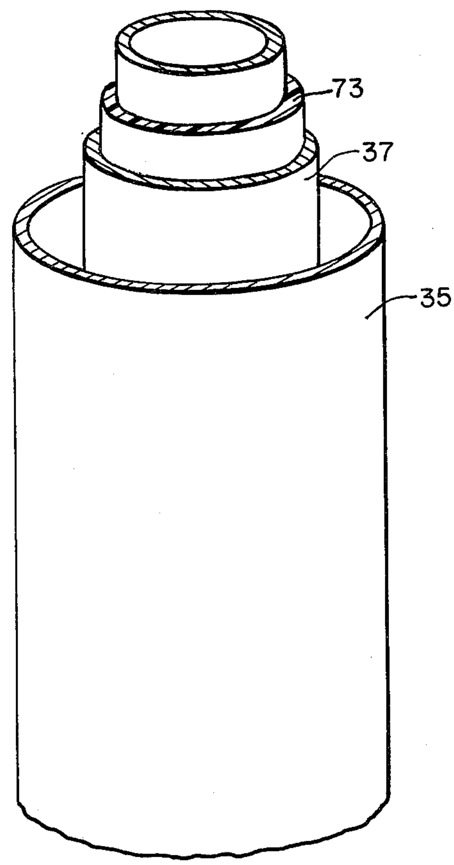


FIG. 15

DOUBLE TUBE HEAT EXCHANGER

BACKGROUND OF THE INVENTION

This invention relates to heat exchangers, and more particularly to steam generators, or reheaters which utilize a liquid metal as the primary fluid.

The demand for electrical power in the United States approximately doubles every decade. While presently fossil fuels provide the majority of the heat energy needed to produce electrical power, in view of the impending fuel shortage, it is estimated that in the next **30** years over **50** percent of our electrical power will be produced utilizing heat energy from nuclear reactors. The supply of fissionable material is limited, so that to meet the continually increasing demand for electrical power, reliable fast breeder reactors, which produce more fissionable material than they consume, must be developed.

In view of the present technology, economical development of fast breeder reactors depends on being able to utilize the favorable heat transfer characteristics of a liquid metal such as sodium, potassium or any combination thereof, as the primary heat exchange medium or fluid.

The primary fluid comes in close proximity to the reactor core and is subjected to a high density of high velocity particles which make it radioactive. The liquid metal contemplated, sodium or potassium, reacts violently when it comes into contact with water or steam; therefore, designs herebefore contemplated, to insure that the radioactive liquid metal does not come into direct contact with the water or steam utilized a secondary liquid metal loop. The secondary liquid metal loop is only subjected to the particles produced by the decaying radioactive primary liquid metal, which do not cause the secondary liquid metal to become radioactive, thus precluding the possibility of a violent reaction between the radioactive liquid metal and the water or steam.

U.S. Pat. No. **3,504,737** describes a heat exchanger in which liquid metal is circulated through one bundle of tubes, water is circulated through another bundle of tubes, and a containment enclose the tube bundles allowing a gas to be circulated over the tube bundles to transfer heat therebetween. While this system reduces the possibility of large scale violent reactions between the liquid metal and the water, it does not transfer heat efficiently.

An efficient heat exchanger steam generator or, reheater into which a radioactive liquid metal, and water or steam could be brought with only an extremely small probability of a liquid metal and water or steam reaction, or such a reaction in which the magnitude of such a reaction would be very small, would allow for a considerable reduction in the cost of liquid metal fast breeder reactors, LMFBR, as this would eliminate the need for a secondary liquid metal loop and all of the associated heat exchangers, piping, pumps and controls.

SUMMARY OF THE INVENTION

Among the objects of this invention is the provision of a reliable heat exchanger in which a radioactive liquid metal can be brought into a vessel containing water or steam and the risk of a violent reaction resulting from leaks is minimal.

In general, a heat exchanger, when made in accordance with this invention, comprises a shell portion, a

first group of tubes through which a primary fluid flows, a second group of tubes through which a secondary fluid flows, the first and second groups of tubes being so disposed that a tube of one group is disposed between a plurality of tubes in the other group, whereby a portion of the heat energy in the fluid in one group of tubes is transferred to the fluid in the other group of tubes.

BRIEF DESCRIPTION OF THE DRAWINGS

The objects and advantages of this invention will become more apparent from reading the following detailed description in connection with the accompanying drawings, in which:

FIG. **1** is a vertical sectional view of a heat exchanger made in accordance with this invention;

FIG. **2** is an enlarged partial sectional view taken on line II—II of FIG. **1**;

FIGS. **3** through **5** are modifications of the partial sectional view shown in FIG. **2**;

FIG. **6** is a partial sectional view taken on line VI—VI of FIG. **5**;

FIGS. **7** and **8** are modifications of the partial sectional view shown in FIG. **6**;

FIG. **9** is an enlarged elevational view of a heat conducting strip made in accordance with this invention;

FIG. **10** is a bottom view of FIG. **9**;

FIG. **11** is a sectional view showing a modification of the conducting strip shown in FIG. **9**;

FIG. **12** is an enlarged partial sectional view of the end of a tube utilized in this invention;

FIG. **13** is a modification of the enlarged partial sectional view shown in FIG. **12**;

FIG. **14** is an enlarged partial sectional view showing the detail of the closures for the heat exchanger; and

FIG. **15** is an enlarged perspective view showing an alternate tube arrangement.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings in detail, FIG. **1** shows a vapor or steam generator comprising a vertical, tubular, or cylindrical shaped shell portion **3** having upper and lower end flanges **5** and **7**, respectively. Disposed within the shell are a first group of tubes or tube bundle **9**, which extends upwardly from a first and second lower tube sheet **11** and **12**, respectively, and a second group of tubes or tube bundle **13** which depends from a first and second upper tube sheet **14** and **15**, respectively. The tube sheets **14** and **15**, and **11** and **12** are separated by upper and lower tubular or cylindrical members **16** and **17**, respectively, which cooperate with the tube sheets to form fluid outlet chambers **19** and **21**. Flanged and dished heads **23** and **25** are disposed to form end closures for the steam generator and cooperate with the tube sheets **12** and **15** to form inlet chambers **27** and **29**.

A liquid metal or primary fluid inlet nozzle **31** is centrally disposed in the lower head **25** and a liquid metal or primary fluid outlet nozzle **32** is disposed in the lower tubular member **17**. Inert gas inlet and outlet nozzles **33** and **34** are disposed in the shell portion **3**.

A plurality of outer tubes **35** extend through holes in the tube sheet **11** and upwardly into the shell portion **3**; the upper ends of the tubes **35** are closed. A plurality of inner tubes **37** extend through holes in the tube sheet

12 and into the outer tube 35. The inner tube 37 terminates adjacent the closed end of the outer tube 35.

A secondary fluid or feedwater inlet nozzle 39 is centrally disposed in the upper head 23 and a secondary flow or stream outlet nozzle 40 is disposed in the upper tubular member 16.

A plurality of outer tubes 41 extend through holes in the tube sheet 14 and downwardly into the shell portion 3. The lower ends of the tubes 41 are closed and a plurality of inner tubes 43 extend through holes in the tube sheet 15 and into the outer tubes 41. The inner tubes 43 terminate adjacent the closed end of the outer tubes 41.

As shown in FIG. 12, the ends of the outer tubes 35 and 41 may be closed by a simple end cap 44, which may be welded to the end of the tubes 35, or 41. Or, as shown in FIG. 13, an end closure 45 may have guide means 46 disposed therein for receiving the ends of the inner tubes 37 and 43, and the ends of the inner tubes 37 and 43 may have openings 47 disposed in the walls thereof to facilitate the flow of fluid from the inner to the outer tube.

The tubes are generally sealed in their respective tube sheets by welding, rolling or a combination thereof or by other sealing means. While the tubes are shown to be disposed on a square pitch, it is understood that triangular and other pitches may be utilized. The outer tubes 35 and 41 are interdigitated; the interdigitating tubes may abut or there may be a space therebetween. The voids between the outer tubes 35 and 41 are filled with a heat transfer material 49, as shown in FIG. 2 to assist in transferring heat from one group of outer tubes to the outer group of outer tubes.

The heat transfer material 49 may take several forms, i.e., as shown in FIGS. 1 and 2, the heat transfer material 49 may be metallic strips 49, which generally extend the length of the interdigitating portions of the outer tubes 35 and 41, and generally have a cruciform shaped cross section.

As shown in FIG. 3, the strips 49′ may have interlocking stepped abutting edges, whereby the strips 49′ remain in place if one or more tubes are removed for inspection, and the interlocking will act as a seal to prevent impingement of leaking fluid on adjacent tubes. Normal strips 49 will lock with tubes — i.e., should not fall out — reason is to avoid leak from impinging on adjacent tube. The strips 49 may also have centrally disposed openings 50 disposed therethrough.

As shown in FIG. 4, the tubes 35′ and 37′, and 41 and 43 may be different sizes and while a square pitch is shown, as noted earlier, a triangular or other pitch may be utilized. The number of tubes utilized for primary fluid may be the same or may differ from the number of tubes utilized for secondary fluid; the difference in the number being dependent upon the specific heat of the fluids, and their heat transfer and flow characteristics. FIG. 4 also shows that strips 49″ of heat transfer material may be non-symmetrical and have a plurality of holes 51 disposed therein.

As shown in FIGS. 5 and 6, the heat transfer material may comprise a plurality of plates 53. The plates 53 have holes 55 therethrough for receiving the tubes, and a plurality of holes 57 for the passage of inert gas. The plates 53 may be stacked adjacent each other and groups of the plates may be separated by insulating plates or pads 59 as the temperature of the tubes 35 and 41 vary along their lengths.

As shown in FIG. 7, the heat transfer material may be particulate material 61 and, depending on the size of the particles and the density to which they are packed, the space between particles may be sufficient to allow inert gas to flow between the particulate material 61. Tubes 63 may be disposed in the particulate matter to allow inert gas to circulate therethrough. The bed of heat transfer particulate material may also be divided by insulating plates or insulating particulate material 65.

In FIG. 8 the heat transfer material disposed to fill the voids may be a fluid 67.

In FIG. 9 the strips of heat transfer material 49‴ disposed between the tubes comprise a plurality of segments and some of the segments may have insulators 67 disposed therebetween.

As shown in FIGS. 9, 10, and 11, the segments may have bosses 67′ disposed on one or more ends thereof; the bosses 67′ may be made integral with the segments or they may fit into grooves 68 disposed in the ends of the segments. The segments 49‴ and bosses 67′ may have holes 50 extending therethrough.

As shown in FIG. 14, the joints between the shell and the tubular members and the heads may comprise any type of standard joint, however, the joints shown are clamped by split rings 69 which have a channel shaped cross section with sloping legs 71 that engage tapers machined on the flanges. However, irrespective of the type of joint utilized, sealed welds are required at the flanges to insure the integrity of the vessel.

Thermal baffles may be disposed inboard of the tube sheets to provide a quiescent zone adjacent the tube sheets to reduce thermal shock on the tubes.

As shown in FIG. 15, the inner tube 37 may have a double wall and the space between the inner and outer portions of the wall may be filled with an insulating material 73, such as magnesium oxide. Inner tubes having a variety of wall thicknesses along their lengths could also be utilized advantageously in such a heat exchanger.

OPERATION OF THE STEAM GENERATOR

Primary fluid, a liquid metal such as sodium, flows through the primary fluid inlet nozzle 31 and into the inlet chamber 39 and then flows into the inner tubes 37, flows upwardly through the tubes 37 and then downwardly inbetween the inner tubes 37 and outer tubes 35 into the primary fluid outlet chamber 21 and then out of the primary fluid outlet nozzle 32. Secondary fluid flows through a secondary fluid inlet nozzle 39 into the secondary fluid inlet chamber 27 and then into the inside of the inner tubes 43. It flows downwardly through the inner tubes 43 and then it returns flowing upwardly inbetween the inner tube 43 and the outer tube 41, picking up heat and changing state from water to steam as it flows upwardly. Steam exits from between the inner and outer tubes and flows into the chamber 19 and then out the secondary fluid or steam outlet nozzle 40.

An inert gas may be supplied via the inert gas inlet nozzle 33 disposed in the shell and by circulating the inert gas through the heat exchange material, picking up heat and then is discharged through the inert gas outlet nozzle 34. This heat energy can be utilized to run a gas turbine, which in turn, operates a compressor. This system would be utilized only when the steam generator is down and it is desirable to remove the decayed heat from the reactor. Providing a pressurized inert gas system allows the inert gas to be maintained at a pressure greater than the liquid metal so that in the eventuality of a leak, the inert gas would leak into the liquid metal portion of the system; and thereby prevent any reaction between the liquid metal and water or steam. The latter would be maintained at a pressure higher than the inert gas so that water or steam would leak into the inert gas system. While the disclosure expressly talks about steam generators, the heat exchanger disclosed could function equally well as a superheater, a reheater or other type of heat exhchanger in which two fluids which must be maintained separate are passed through a single vessel and heat is exchanged between the fluids.

The heat exchanger hereinbefore described advantageously provides for efficient heat transfer between a primary and a secondary fluid, and also provides an intermediate chamber between the fluids to eliminate the possibility of the fluids coming into contact, or at least limits the quantity of the fluids that may come into contact so that radioactive liquid metal can be utilized as the primary fluid and water and steam can be utilized as the secondary fluid, and the probability of a large scale reaction between the two materials is within acceptable bounds.

While this type of heat exchanger is ideally suited to be utilized in liquid metal fast breeder reactors, its use is not limited thereto as it could be advantageously utilized in pressurized water reactors as well, to improve the integrity of the primary loop, and thereby improve the reliability of the pressurized water reactor power plants.

What is claimed is:

1. A heat exchanger comprising a shell portion, a first group of tubes through which a primary fluid flows, a second group of tubes through which a secondary fluid flows, said first and second groups being so disposed that a tube of one group is disposed between a plurality of tubes in the other group, heat conducting means disposed between said tubes engaging at least one tube in each group, said heat conducting means being segmented, and insulating means being disposed between segments of said heat conducting means, whereby a portion of the heat energy in the fluid in the one group of tubes is transferred via the heat conducting means to the fluid in the other group of tubes.

2. A heat exchanger as set forth in claim **1,** wherein the tubes in each group comprises an outer tube and an inner tube disposed within the outer tube and insulating means encompassing said inner tube.

3. A heat exchanger as set forth in claim **2,** wherein the plates have openings between the holes for the passage of a gas.

4. A heat exchanger as set forth in claim **1,** wherein the heat conducting means disposed between said tubes is so disposed to engage a plurality of tubes in each group.

5. A heat exchanger as set forth in claim **4,** wherein the heat conducting means comprises a plurality of plates, each plate having a plurality of holes for receiving the tubes.

6. A heat exchanger as set forth in claim **4,** wherein the heat conducting means comprises strips having four arcuate surfaces which engage the tubes generally providing a maximum amount of engagement between said strips and the tubes.

7. A heat exchanger as set forth in claim **6,** wherein the shell has gas inlet and gas outlet means disposed therein and the openings in the strips form passageways for the gas to flow therethrough and the passageways are so disposed to allow the gas to flow from the gas inlet means through the passageways to the gas outlet means.

8. A heat exchanger as set forth in claim **6,** wherein the strips have openings extending therethrough and the openings are disposed adjacent the central portion thereof.

9. A heat exchanger as set forth in claim **8,** wherein the strips are generally cruciform in shape and have interlocking steps on each arm of the cruciform to lock the strips in position even when one or more tubes are removed from the heat exchanger.

* * * * *