United States Patent

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[15] **3,670,810**

[45] **June 20, 1972**

[54] HEAT EXCHANGER

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[22] Filed: **Jan. 15, 1971**

[21] Appl. No.: **106,863**

[52] **U.S. Cl.** **165/70**, 165/81, 165/134, 165/158

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

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

[56] **References Cited**

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Primary Examiner—Carroll B. Dority, Jr.

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[57] **ABSTRACT**

A heat exchanger characterized by a vessel containing a plurality of tubes passing therethrough and an upper cover assembly having a first ring-shaped tube sheet and a header assembly mounted on said cover assembly and having a second ring-shaped tube sheet disposed above said first tube sheet in spaced relationship to a drain space between the two tube sheets, and means for connecting the header to the vessel to provide expansion movement of the header assembly with respect to the vessel.

12 Claims, 9 Drawing Figures

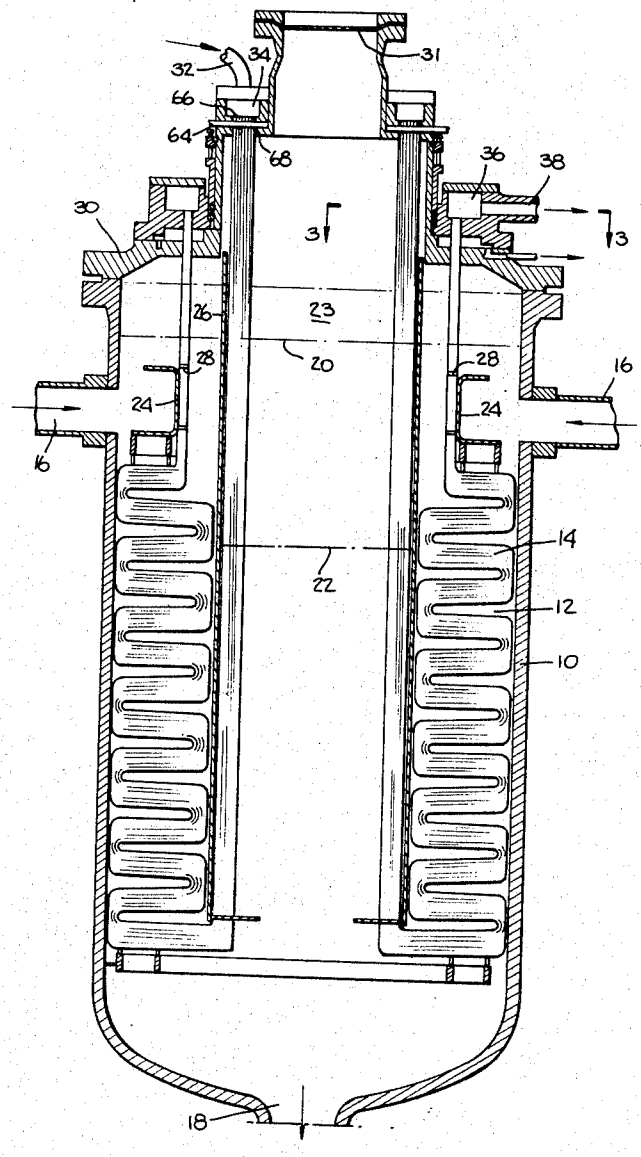
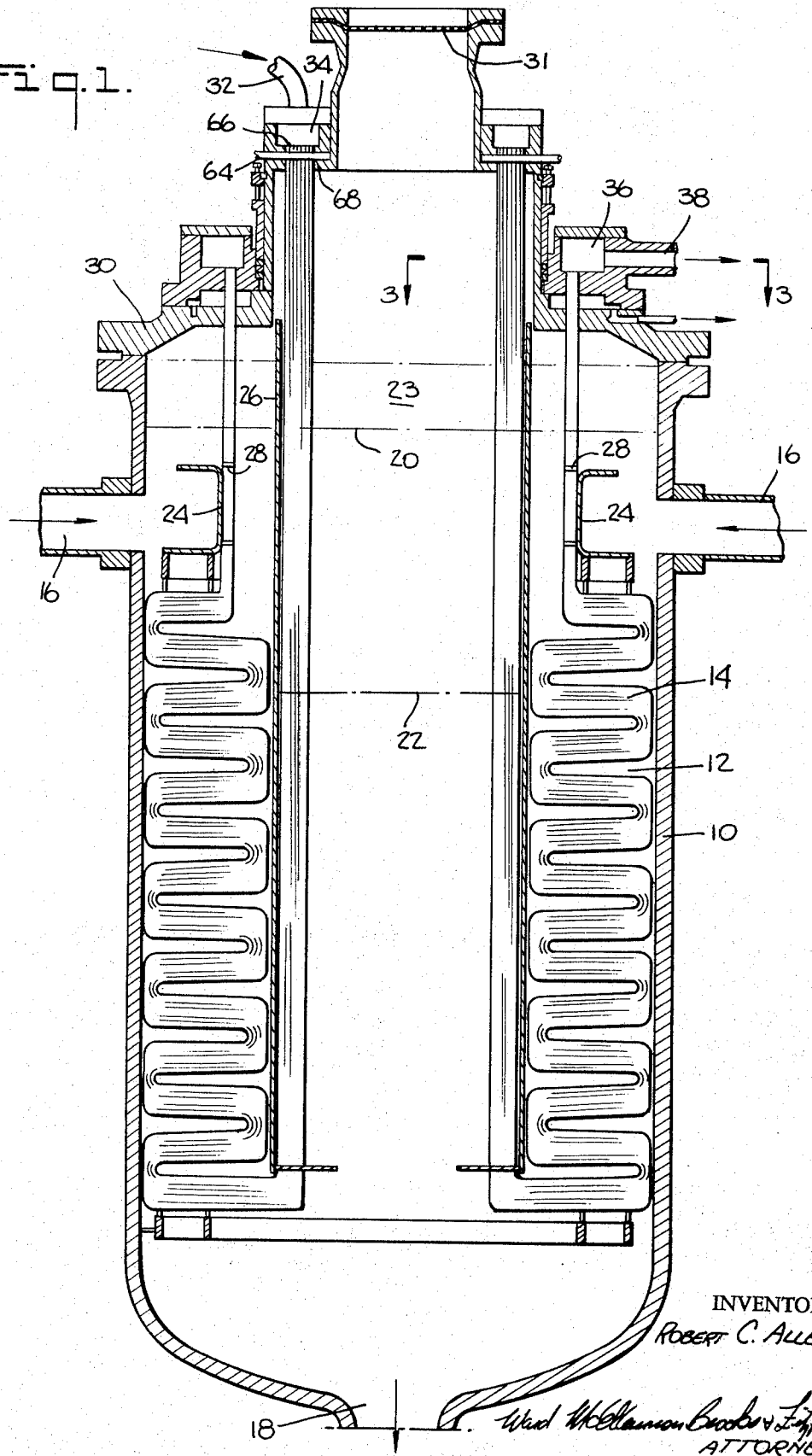


Fig. 1.



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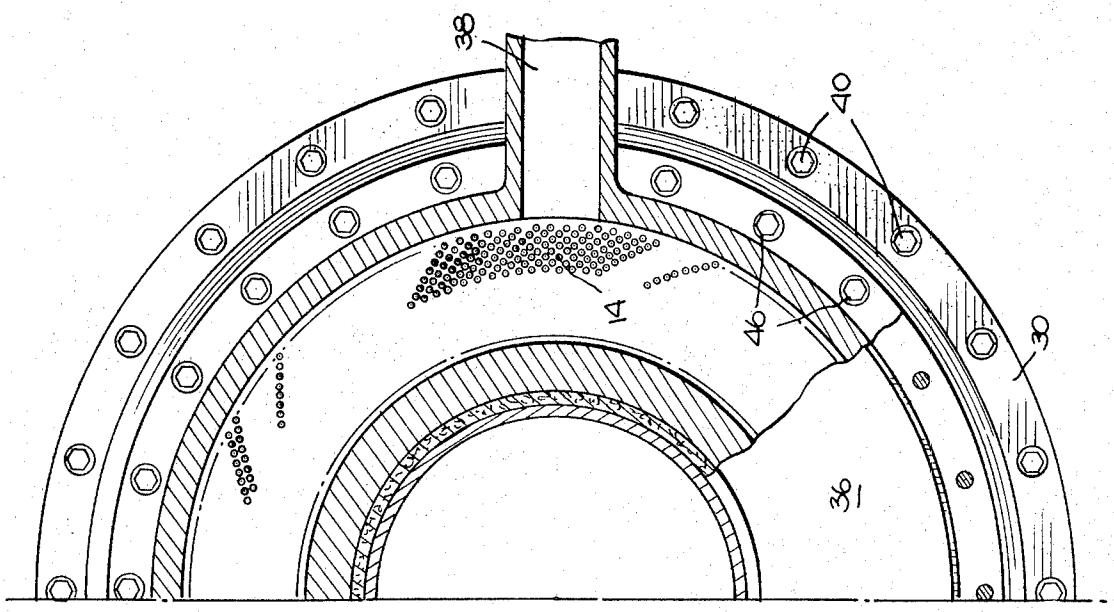


Fig. 3.

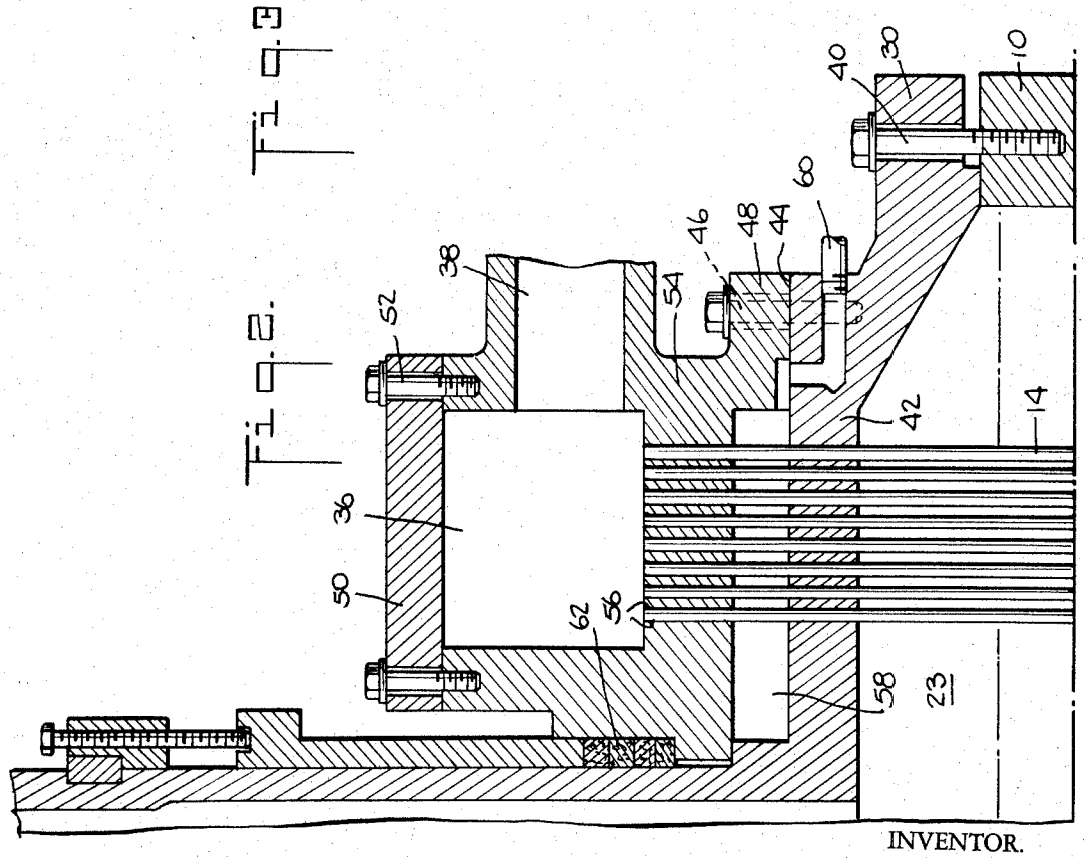


Fig. 2.

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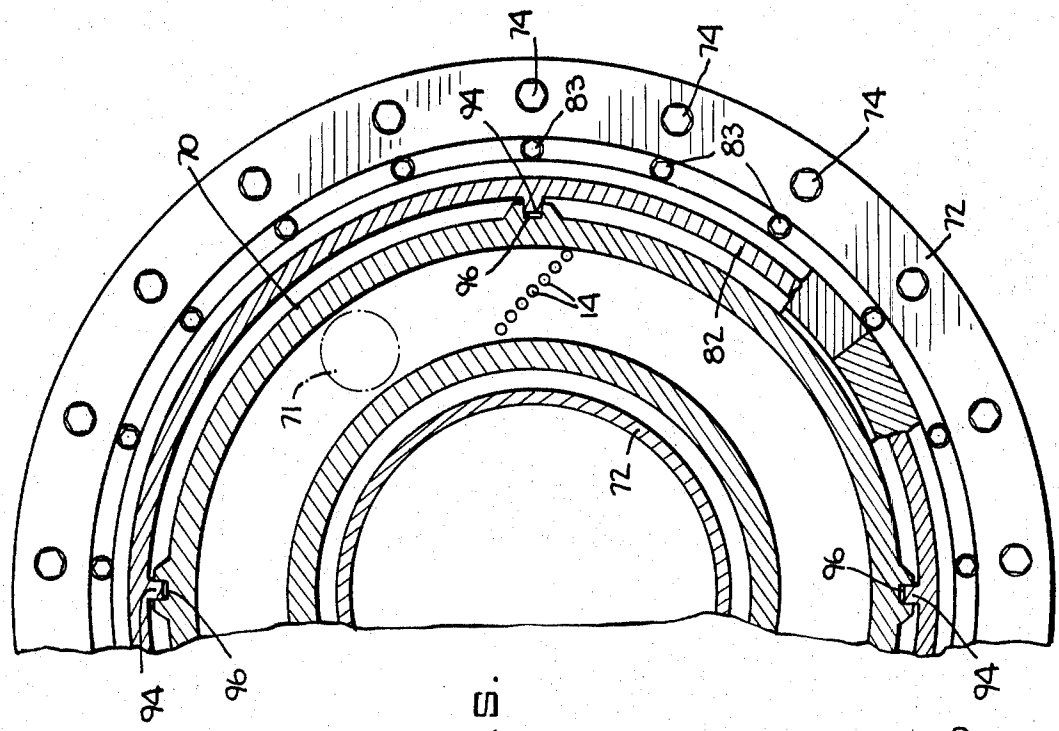


FIG. 5.

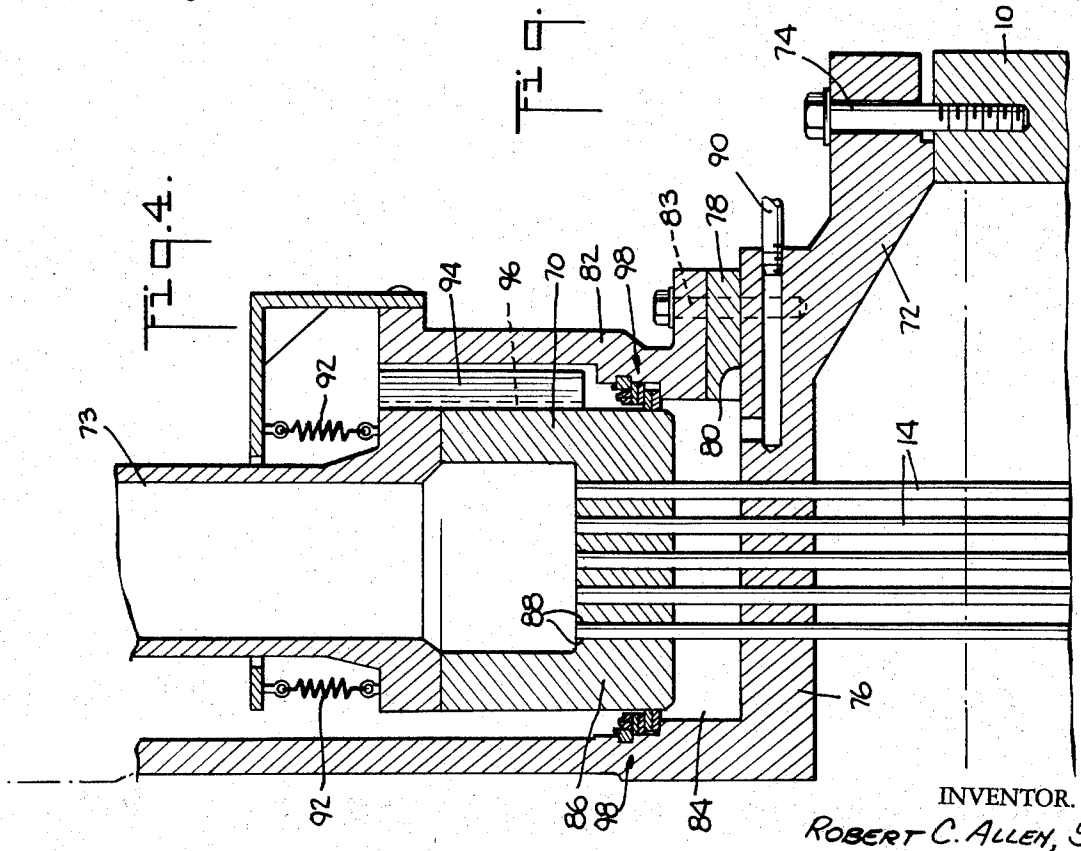


FIG. 4.

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Fig. 6.

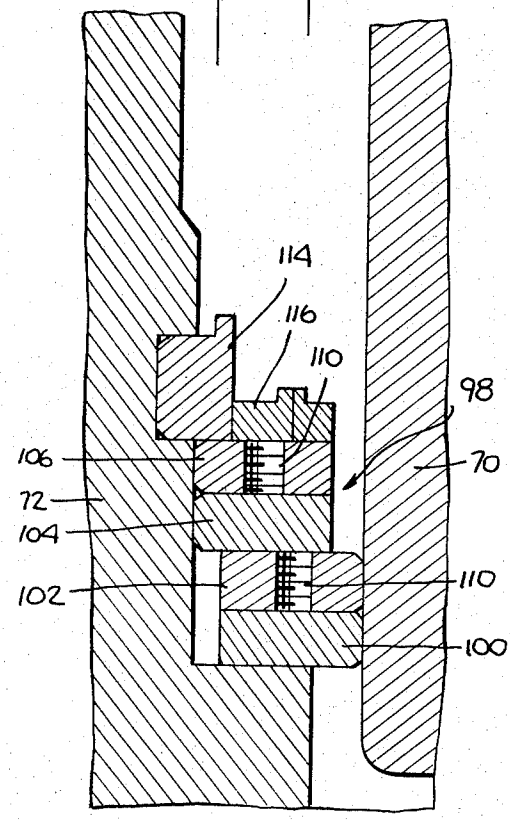
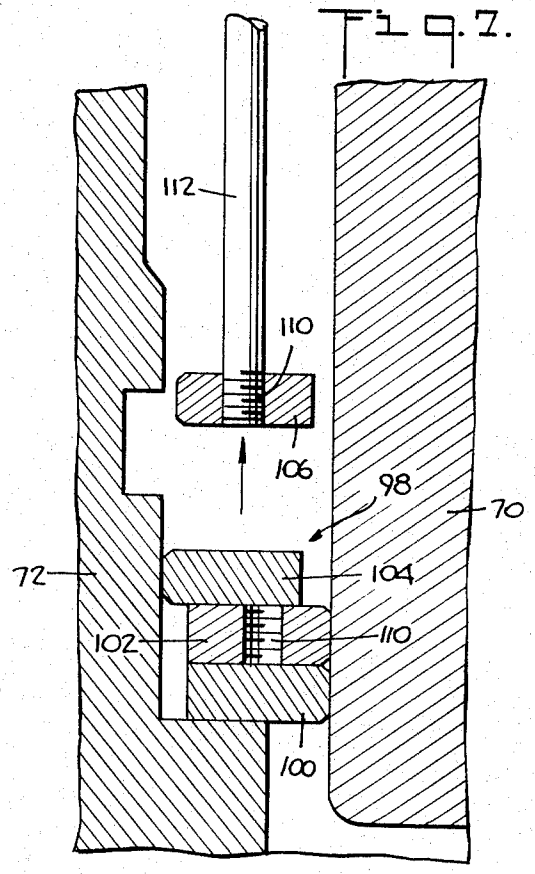


Fig. 7.



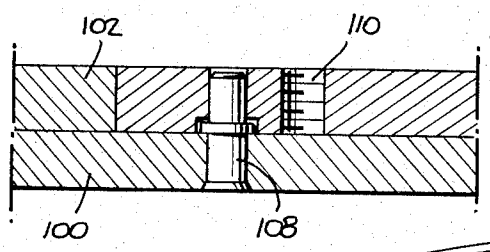
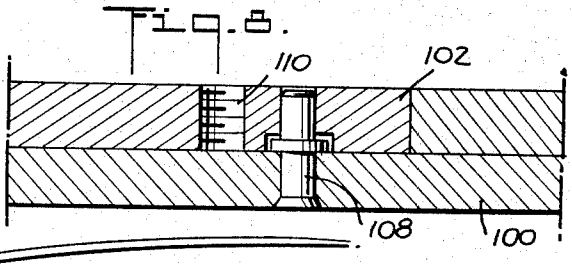


Fig. 8.



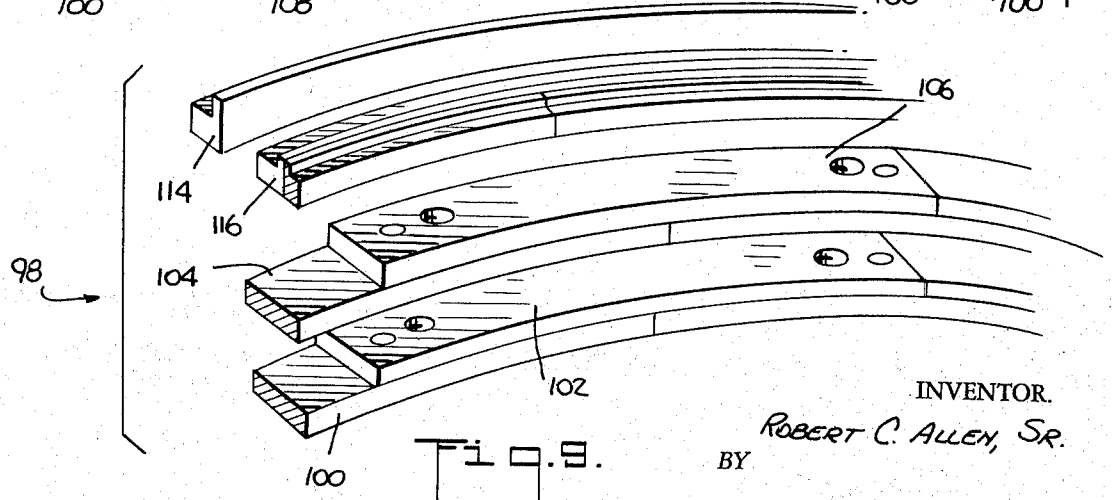


Fig. 9.

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HEAT EXCHANGER

This invention relates to heat exchangers and it is particularly adapted, among other possible uses, for preventing water or steam leakage into sodium in steam generators heated with liquid sodium, for example. Steam generators of this nature are particularly suited for use in conjunction with nuclear reactors.

Heretofore, double tubes with double tube sheets were employed in steam generators or heat exchangers to prevent mixture of the main flows of the cycling fluids when leakage occurred. These introduced heat transfer resistance and were expensive and difficult to fabricate. My contribution to the art is a new heat exchanger which is an improvement over such prior art devices, and it involves a novel combination of features combined in such a way as to afford a very effective solution to the difficulties encountered with the prior art, as will become apparent as the description proceeds. Related patents in this art include:

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Briefly, my invention contemplates the provision of a new and improved heat exchanger characterized by a vessel having an internal heat exchange chamber with a plurality of heat exchange tubes passing therethrough. The vessel is provided with a cover which contains a first tube sheet. An upper header means is mounted on said cover and contains a second tube sheet which is disposed in spaced relationship with respect to the first tube sheet, thereby providing a space between the tube sheets for draining off fluid leaking from the header as well as fluid leaking from the main portion of the vessel. Means are provided for connecting the header to the vessel cover, which allows for differential expansion therebetween.

There has thus been outlined rather broadly the more important features of the invention in order that the detailed description thereof that follows may be better understood, and in order that the present contribution to the art may be better appreciated. There are, of course, additional features of the invention that will be described more fully hereinafter. Those skilled in the art will appreciate that the conception on which this disclosure is based may readily be utilized as the basis for the designing of other structures for carrying out the several purposes of the invention. It is important, therefore, that this disclosure be regarded as including such equivalent constructions as do not depart from the spirit and scope of the invention.

Several embodiments of the invention have been chosen for purposes of illustration and description, and are shown in the accompanying drawings, forming a part of the specification, wherein:

FIG. 1 is a medial, longitudinal, sectional view of a vertically disposed steam generator constructed in accordance with the concept of this invention;

FIG. 2 is an enlarged, fragmentary view of a portion of the steam generator of FIG. 1, showing details of the header means, double tube sheets and heat exchanger tubes;

FIG. 3 is an enlarged, sectional view taken along the line indicated at 3—3 in FIG. 1;

FIG. 4 is an enlarged, fragmentary view of a portion of a steam generator similar to FIG. 2, but showing a modified form of connection between the header means and the tube sheets;

FIG. 5 is an enlarged, sectional view similar to FIG. 3, but showing the form of connection between the header means and the tube sheets of FIG. 4;

FIGS. 6 and 7 are enlarged, fragmentary, longitudinal, sectional views showing details of seal rings interposed between the upper and lower tube sheets;

FIG. 8 is an enlarged, fragmentary, longitudinal, sectional view of the seal rings and alignment pins; and

FIG. 9 is an enlarged, exploded, perspective view showing the sealing ring assembly.

In FIG. 1 there is shown a sodium heated steam generator comprising a vessel 10 having an internal heat exchange chamber 12, and a plurality of heat exchanger tubes 14 passing through said heat exchange chamber 12. The vessel is provided with upper sodium inlets 16 and a lower sodium outlet 18. Normally, in a steam generator of this type, sodium which has been heated in a nuclear reactor (not shown) is received through the sodium inlet and passes downwardly through the vessel 10 wherein it gives up heat to a medium such as steam and then passes out through the outlet 18 and back to the nuclear reactor, thereby forming a closed cycle. The operating level of the liquid sodium in the vessel is between an upper level 20 and a lower level 22. The space 23 above the liquid sodium is filled with argon under a slight positive pressure. Shroud baffles 24 are mounted adjacent the sodium inlets and an internal shroud 26 is provided. The tubes 14 are retained by means of restraint clips 28. The vessel 10 is closed by means of a steam cover 30 and, for protection purposes, a relief diaphragm 31 is mounted on the top thereof.

Still referring to FIG. 1, a water inlet 32 is provided, which receives water from a condenser, (not shown) in a conventional steam plant, for example. Water passes through the inlet and into a ring-shaped water header assembly 34, from where it passes into the tubes 14. Tubes 14 pass through the heat exchanger 12 wherein the water is converted into steam before returning to a ring-shaped steam header assembly 36, and an outlet 38. Normally the steam is led to a steam turbine (not shown) when the heat exchanger is employed in conjunction with a conventional steam power plant.

As best seen in FIG. 2, I provide, according to my invention, a construction which permits differential expansion between the steam header assembly 36 and the cover 30, FIGS. 2 and 3. This cover is fixedly attached to the vessel 10, as by means of bolts 40, and it carries as an integral portion thereof a first ring-shaped tube sheet 42, FIG. 2, through which the tubes 14 pass. Sufficient gas tightness between the tubes and the first tube sheets by conventional rolling procedures is carried out from the outside of the cover. The steam header assembly 36 is a separate ring-shaped casting which is mounted on a surface 44 of the cover 30 by means of bolts 46. Bolt holes 48 in the header assembly 36 are fabricated substantially larger than the bolts 46 to permit radial movement of the header assembly 36 with respect to the cover 30. That is, the bolts 46 restrain the header from vertical movement with respect to the cover, but they permit radial sliding movement at the support surface, due to the differential expansion caused by the temperature difference between the outlet steam and the adjacent structure.

The steam header assembly 36, FIG. 2, is closed by means of a top closure plate 50 bolted thereon, as by means of bolts 52. This plate is removable to provide access to the upper ends of the tubes 14. The steam header assembly carries as an integral part thereof a second ring-shaped tube sheet 54 for receiving the upper ends of the tubes 14 in fluid flow relation. The tubes are connected to the tube sheet 54 by rolling and welding, as at 56. The second tube sheet 54 is spaced from the first tube sheet 42 to provide a drain space 58 therebetween. The vertical height of the drain space is selected based on the bending stresses in the tubes. A plurality of spaced drain openings 60 are provided around the periphery of the cover for removing leakage containing small amounts of water, water vapor, argon gas, hydrogen gas and sodium hydroxide. The total amounts of this leakage can easily be taken care of by established disposal means available in all nuclear plants. In a typical installation, the pressure in the steam header 36 is of the order of about 2,400 p.s.i. and the pressure in the leak-off space 58 is approximately equal to that of the atmosphere. The argon cover gas 23 has a pressure which is higher than atmosphere pressure by about a few inches water gauge. Ac-

cordingly, leakage from both directions is toward the drain space **58**. The leakage with rolled tubes is very small, so that the sodium vapor which reaches the drain space through the argon gas is practically negligible. The construction provides for a tube failure. The greater probability is that a tube failure would permit the flow of water or steam into the drain space **58**. A sufficient number of drains are provided for accommodating this flow in order to prevent the steam pressure in this space from exceeding the argon pressure below the first tube sheet **42** in the event of a complete failure of one tube.

Seal rings **62**, FIG. **2**, are interposed between the steam header **36** and the cover **30** for preventing leakage from the drain space **58**. This seal allows radial expansion movement between the two members.

It will be particularly appreciated that the water header assembly **34**, FIG. **1**, is constructed in a manner substantially the same as the steam header assembly **36** to permit differential expansion between the water header assembly and the cover **30** and to provide a drain **64** between a first tube sheet **66** and a second tube sheet **68**.

When the temperature difference between the water inlet and steam outlet and their respective adjacent structures is sufficiently great to result in objectionable stresses in the space between the first and second tube sheets, the embodiment of FIGS. **4–9** is employed. In this embodiment there is a ring-shaped steam header assembly **70** which is mounted on a cover assembly **72**. The steam header assembly **70** has a steam outlet **73**. The cover is fixedly attached to the vessel **10**, as by means of bolts **74**, and it carries as an integral portion thereof, a first ring-shaped tube sheet **76**, FIG. **4**, through which the tubes **14** pass. Conventional rolling procedures carried out from the outside of the cover provide substantial gas tightness between the tubes and the first tube sheet **76**. Removable half-rings **78** are mounted on the cover **72** as at **80**, and the cover assembly further comprises an annular support member **82** which is mounted together with the half-rings on the surface **80** by means of bolts **83**. The half rings are removable for purposes of providing access to a drain space **84**.

The ring-shaped steam header assembly **70**, FIG. **4**, carries as an integral part thereof a second ring-shaped tube sheet **86** for receiving the upper ends of the tubes **14** in fluid flow relationship. The tubes are connected to the tube sheet **86** by rolling and welding at **88**. The second tube sheet **86** is spaced from the first tube sheet **76**, thereby providing a drain space **84**. This drain space serves for removing an accumulation of sodium oxide that could form if excessive leakage occurred at the tube junctions at the steam ends concurrently with argon containing sodium vapor leaking from the first tube sheet. A plurality of spaced drain openings **90** are provided around the periphery of the cover **72** for removing the leakage. The drain openings are connected to conventional disposal means available in all nuclear plants. The construction provides for tube failure in a manner similar to that described hereinbefore in connection with the embodiment of FIGS. **2** and **3**.

The ring-shaped steam header assembly **70**, FIG. **4**, is substantially free-floating. That is, it is not supported vertically except by the tubes **14** and external spring supports **92**. Weighted levers could be used instead of the spring supports, if desired. As seen in FIGS. **4** and **5**, the annular support member **82** has four equally spaced vertically disposed elongated keys **94**, which fit into keyways **96** in the header assembly **70**, thereby to provide adequate rigidity in the three rotational degrees of freedom and the two translational degrees, but permitting free movement in the vertical direction. FIG. **5** shows that radial differential expansion between the floating steam header assembly **70** and the member **82** portion of the cover assembly **72** is not restrained.

Sealing means, indicated generally at **98**, FIG. **4**, are interposed between the free floating steam header assembly **70** and the cover assembly **72**. As best seen in FIGS. **6–9**, this sealing means comprises a first pair of sealing rings including a lower ring **100** and an upper ring **102** which are mounted for engagement with the header assembly **70**, and a second pair of sealing rings comprising a lower ring **104** and an upper ring **106** which are mounted for engagement with the cover assembly **72**. The sealing rings are in the form of segments and are provided with alignment pins **108**, FIG. **8**, for keeping the ring halves in horizontal alignment. As best seen in FIG. **7**, the rings are provided with tapped holes **110** for removal by means of a threaded bar **112**. A first segmented retainer **114**, FIGS. **6** and **9**, retains the sealing rings in vertical position and a second segmented retainer **116** retains the first retainer in position. It will be appreciated that the sealing means **98** may be removed without disturbing the tubes. In addition, the sealing means permits free radial and vertical movement of the steam header.

It will be appreciated that the water header assembly **34**, FIG. **1**, could also be constructed in a manner substantially the same as the steam header assembly described in connection with FIGS. **4–9** to permit differential expansion between the water header assembly and the cover of the vessel.

It will thus be seen that the present invention does indeed provide an improved heat exchanger which is superior in simplicity, economy and efficiency as compared to prior art devices.

Although certain particular embodiments of the invention are herein disclosed for purposes of explanation, various modifications thereof, after study of the specification will be apparent to those skilled in the art to which the invention pertains.

What is claimed and desired to be secured by Letters Patent is:

1. A heat exchanger comprising a vessel having an internal heat exchange chamber, a plurality of tubes passing through said chamber, header means mounted towards the upper end of said vessel, an upper ring-shaped tube sheet forming a bottom portion of said header means, a spaced lower ring-shaped tube sheet forming a drain space between said tube sheets, said tubes passing through said sheets and the ends thereof opening onto said header means, said tubes being connected to said lower tube sheet by rolling and said tubes being connected to said upper tube sheets by rolling and welding, said lower tube sheet being fixedly connected to said vessel, means for connecting said upper tube sheet to said lower tube sheet to prevent vertical movement and to allow lateral movement therebetween.

2. A heat exchanger comprising a vessel having an internal heat exchange chamber, a plurality of heat exchange tubes passing through said heat exchanger chamber, an upper cover assembly for said vessel, a ring-shaped header assembly, means mounting said header assembly on said cover assembly to prevent vertical movement and to allow lateral movement therebetween, an outlet for said header assembly, said cover assembly carrying a first ring-shaped tube sheet through which said tubes pass, means for substantially limiting the leakage between said tubes and said tube sheet, said steam header assembly carrying as an integral part thereof a second ring-shaped tube sheet for receiving the upper ends of said tubes in fluid flow relation, means for substantially limiting the leakage between said tubes and said second tube sheet, said second tube sheet being spaced from said first tube sheet to provide a drain space therebetween, drain means for removing leakage from said drain space, and seal rings being interposed between the steam header and the cover assembly for preventing leakage from said drain space.

3. A heat exchanger according to claim **2** wherein said vessel has upper water inlets and lower steam outlets and wherein said heat exchanger further comprises a ring-shaped water header assembly mounted on said cover assembly for receiving water from a water inlet, said tubes being connected to said water header assembly in fluid flow communication.

4. A heat exchanger according to claim **2**, wherein said tubes are connected to said first tube sheet by rolling, and wherein said tubes are connected to said second tube sheet by rolling and welding, and wherein said drain means for removing leakage from said drain space comprises a plurality of

spaced drain openings disposed around the periphery of the cover assembly.

5. A heat exchanger according to claim 2 wherein said means mounting said header assembly on said cover assembly to prevent vertical movement and to allow lateral movement therebetween comprises bolts extending between said steam header assembly and said cover assembly, the bolt holes in said steam header assembly being of substantially larger diameter than the diameter of the bolts.

6. A heat exchanger comprising a vessel having an internal heat exchange chamber, a plurality of heat exchange tubes passing through said heat exchange chamber, said vessel having upper sodium inlets and a lower sodium outlet, an upper cover assembly for said vessel, a ring-shaped water header assembly mounted on said cover assembly for receiving water from a water inlet, said tubes being connected to said header assembly in fluid flow communication, a ring-shaped steam header assembly, means mounting said steam header assembly on said cover assembly, an outlet for said steam header assembly, said cover assembly carrying a first ring-shaped tube sheet through which said tubes pass, said tubes being connected to said first tube sheet by rolling, said means mounting said steam header assembly on said cover assembly comprising bolts mounted in enlarged bolt holes in said steam header assembly to permit radial movement of said steam header assembly with respect to said cover assembly, said steam header assembly carrying as an integral part thereof a second ring-shaped tube sheet for receiving the upper ends of said tubes in fluid flow relation, said tubes being connected to said second tube sheet by rolling and welding, a top closure plate for said steam header, said top closure plate being removable for providing access to the upper ends of said tubes, said second tube sheet being spaced from said first tube sheet to provide a drain space therebetween, a plurality of spaced drain openings being provided around the periphery of the cover assembly for removing leakage from said drain space, and seal rings being interposed between the steam header and the cover assembly for preventing leakage from said drain space.

7. A heat exchanger comprising a vessel having an internal heat exchange chamber, a plurality of tubes passing through said chamber, a cover assembly for closing said chamber, said cover assembly having as an integral portion thereof a first ring-shaped tube sheet through which said tubes pass, means for substantially limiting the leakage between said tubes and said tube sheet, a ring-shaped header assembly having as an integral part thereof a second ring-shaped tube sheet for receiving the upper ends of said tubes in fluid flow relation, means for substantially limiting the leakage between said tubes and said second tube sheet, said second tube sheet being spaced from said first tube sheet thereby providing a drain space, drain means for removing leakage from said drain space, said header assembly being substantially free floating except for support furnished by said tubes, means for aligning said header assembly with respect to said cover assembly, sealing means interposed between the header assembly and said cover assembly.

8. A heat exchanger according to claim 7 wherein said tubes are connected to said first tube sheet by rolling and wherein said tubes are connected to said second tube sheet by rolling and welding and wherein means are included for providing access to said drain space.

9. A heat exchanger according to claim 7 further comprising spring support means interposed between said cover assembly and said header assembly for providing support for said header assembly.

10. A heat exchanger according to claim 7 wherein said means for aligning said header assembly with respect to said cover assembly comprises four spaced vertically disposed elongated keyways in said cover assembly and said header assembly having mating keyways for receiving said keys.

11. A heat exchanger according to claim 7 wherein said sealing means comprises a first pair of sealing rings including a lower ring and an upper ring which are mounted for engagement with the header assembly, and a second pair of sealing rings including a lower ring and an upper ring which are mounted for engagement with the cover assembly, said sealing rings being in the form of segments and being provided with alignment pins for keeping said rings in horizontal alignment, said rings being provided with tapped holes for removal, a first segment retainer retaining the sealing rings in vertical position and a second segment retainer for retaining the first retainer in position whereby said sealing means may be removed without disturbing said tubes and whereby said sealing means permit free radial and vertical movement of said header assembly.

12. A heat exchanger comprising a vessel having an internal heat exchange chamber, a plurality of tubes passing through said chamber, a cover assembly for closing said chamber, said cover assembly having as an integral portion thereof a first ring-shaped tube sheet through which said tubes pass, said tubes being connected to said first tube sheet by rolling, said cover assembly further comprising an annular support member, a ring-shaped header assembly having as an integral part thereof a second ring-shaped tube sheet for receiving the upper ends of said tubes in fluid flow relation, said tubes being connected to said second tube sheet by rolling and welding, said second tube sheet being spaced from said first tube sheet thereby providing a drain space, half-rings being removably mounted on said cover for providing access to said drain space, said cover providing a plurality of spaced drain openings for said drain space, spring support means interposed between said cover and said annular support member, said steam header assembly being substantially free floating except for support furnished by said tubes and said external spring supports, said annular support member having four equally spaced vertically disposed elongated keys, said header assembly having mating keyways for said keys, sealing means interposed between the steam header assembly and said cover assembly, said sealing means comprising a first pair of sealing rings including a lower ring and an upper ring which are mounted for engagement with the header assembly, and a second pair of sealing rings including a lower ring and an upper ring which are mounted for engagement with the cover assembly, said sealing rings being in the form of segments and being provided with alignment pins for keeping said rings in horizontal alignment, said rings being provided with tapped holes for removal, a first segmented retainer retaining the sealing rings in vertical position and a second segmented retainer for retaining the first retainer in position whereby said sealing means may be removed without disturbing said tubes and whereby said sealing means permits free radial and vertical movement of said steam header assembly.

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