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[73] Assignee **The United States of America as**
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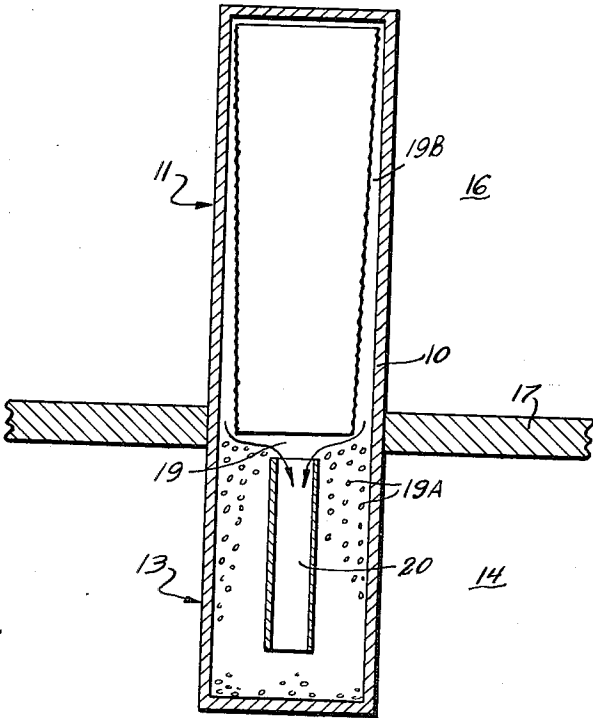
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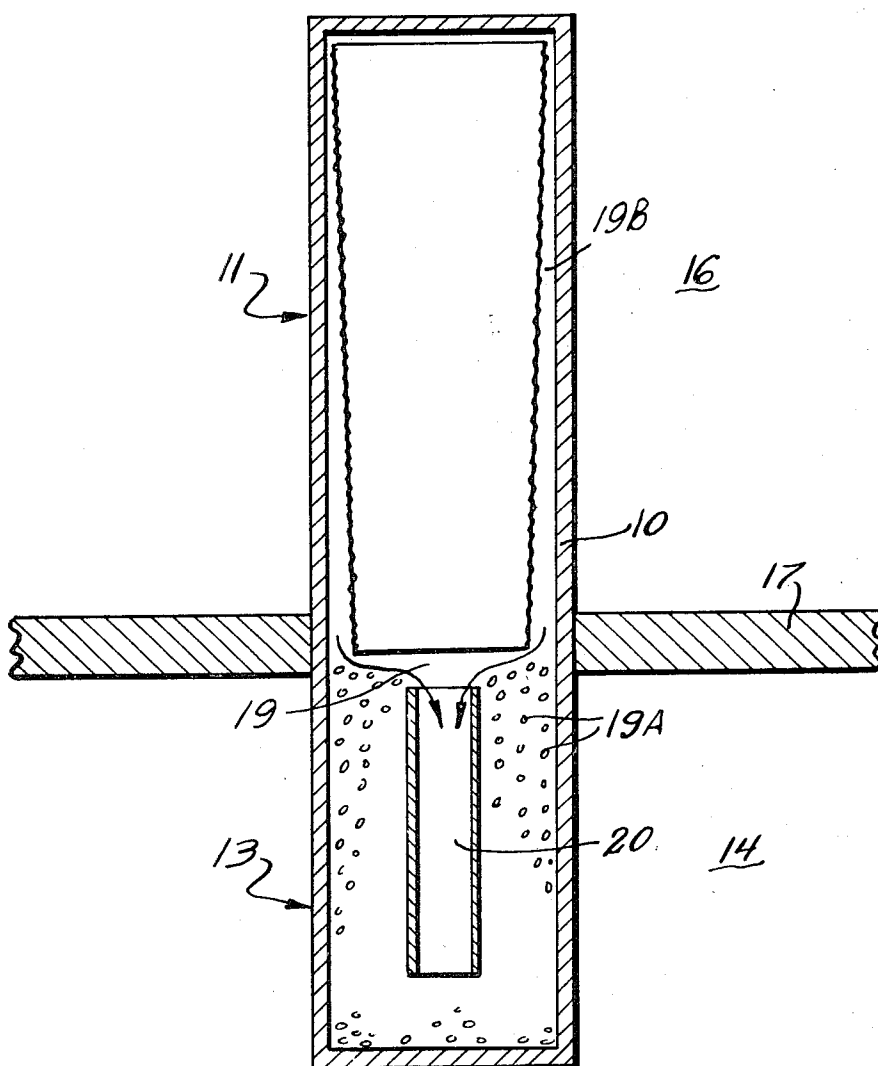
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[54] **HEAT EXCHANGER USING THERMAL CONVECTION TUBES**
1 Claim, 6 Drawing Figs.
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122/32
[51] Int. Cl..... **F28d 15/00**
[50] Field of Search..... **165/105,**
106; 122/367 A, 32, 33
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ABSTRACT: A heat exchanger is constructed with the hotter fluid in a lower region and the cooler fluid in an upper region. A single wall separates the two regions. Vertically mounted thermal convection tubes extending from the hotter fluid to the cooler fluid through the wall act to transfer heat between the fluids. The thermal convection tubes contain a working fluid and provide for substantially isothermal heat transfer, the latent heat of vaporization of the working fluid being the primary mechanism responsible for this heat transfer.





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Fig-2

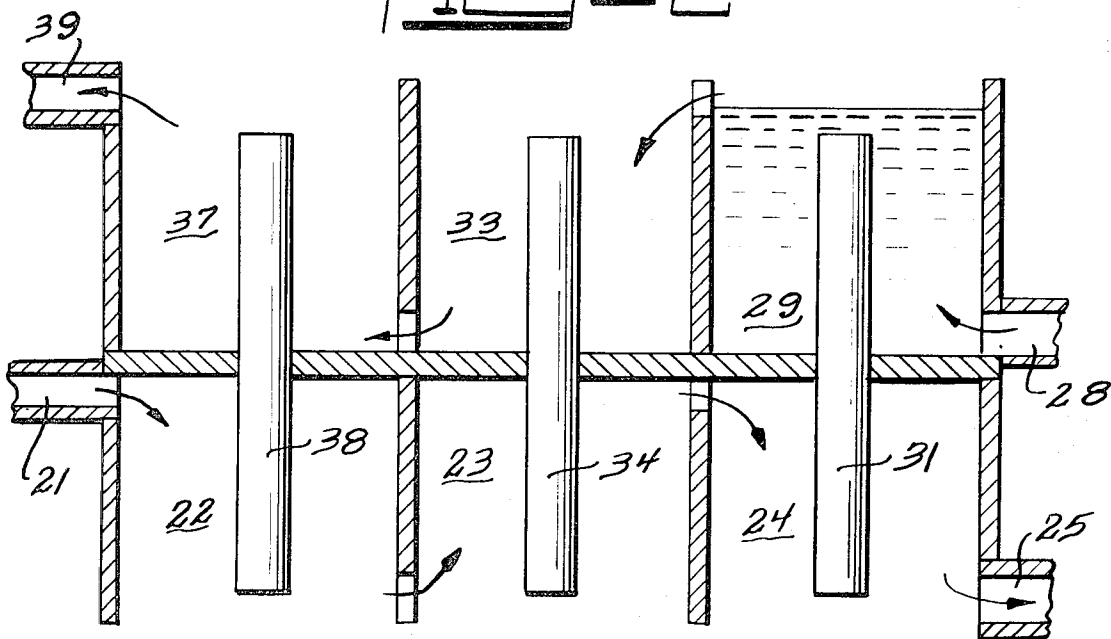


Fig-5

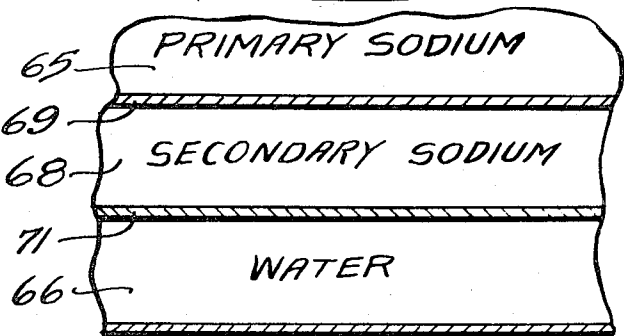
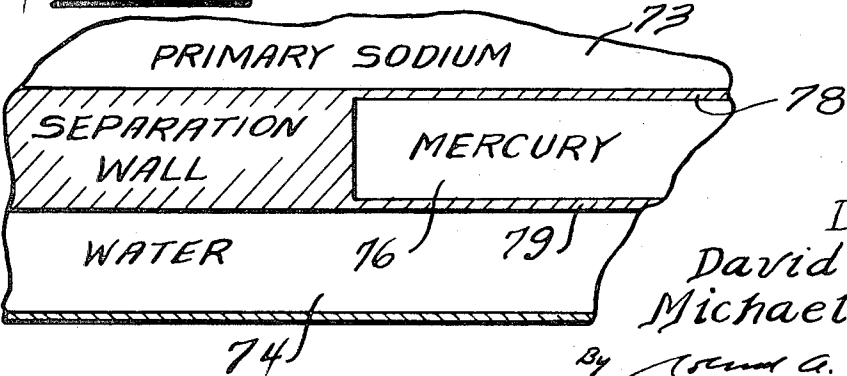


Fig-6



PRIOR ART

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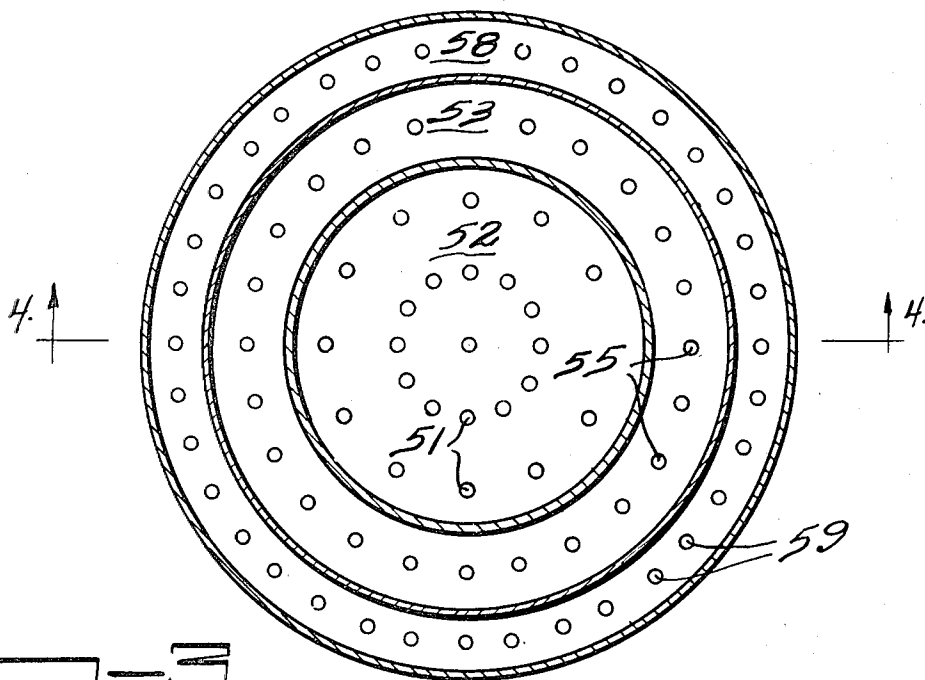


Fig. 3

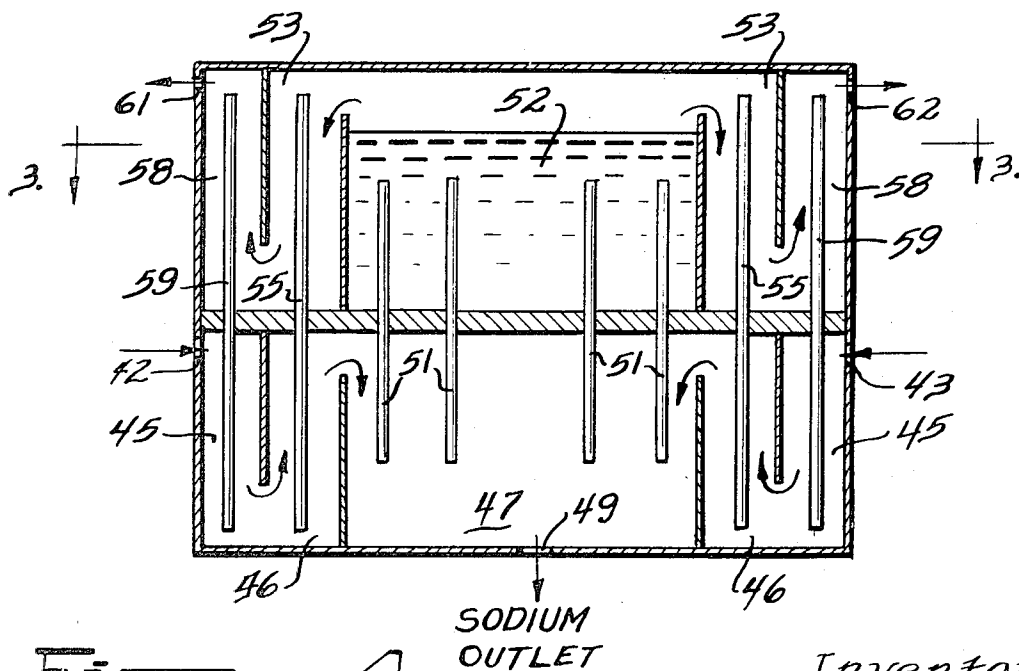


Fig. 4

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HEAT EXCHANGER USING THERMAL CONVECTION TUBES

CONTRACTUAL ORIGIN OF THE INVENTION

The invention described herein was made in the course of, or under, a contract with the UNITED STATES ATOMIC ENERGY COMMISSION.

BACKGROUND OF THE INVENTION

To date, the development of heat exchangers for use in liquid metal breeder reactors has been predominantly in the area of conventional type shell and tube heat exchangers. In order to isolate the water from the primary sodium which circulates through the reactor and which is radioactive, a secondary sodium loop is employed. This requires two heat exchangers, one to transfer heat from the primary sodium to the secondary sodium and one to transfer heat from the secondary sodium to the water. However, the water is still adjacent liquid sodium and hazards of a sodium-water reaction resulting from a leak are present. Another problem is in the welds used in the construction of the shell and tube heat exchangers. The welded regions are subject to considerable stress and are the source of many failures.

Heat pipes are known to have the ability to transfer relatively large quantities of heat at small thermal gradients. However, heat pipes have had relatively short lifetimes compared to the requirements for nuclear reactor application. The interaction of the working fluid with the heat pipe walls creates a residue of material which has been found to accumulate at the boiler section of the heat pipe. The residue acts to obstruct the return flow of the working fluid through the wick passages of the heat pipe.

It is therefore an object of this invention to provide a heat exchanger wherein sodium-water contact does not occur subsequent to a single tube rupture.

Another object of this invention is to provide a heat exchanger wherein exchanger elements are not rigidly fastened at each end, thus substantially reducing stress problems.

Another object of this invention is to provide a single heat exchanger in place of the primary and intermediate heat exchangers used in liquid-metal nuclear reactors.

Another object of this invention is to provide a heat exchanger wherein boiling and superheating take place in separate chambers.

Another object of this invention is to provide a heat exchanger having a lifetime compatible with nuclear reactor requirements by employing wickless heat pipes, "thermal convection tubes."

SUMMARY OF THE INVENTION

In practicing this invention a heat exchanger is provided having two regions with one region positioned above the other and separated therefrom by a separation wall. The lower region contains a first fluid which may be, for example, liquid sodium. The second region contains a second cooler fluid which may be, for example, water. A sealed hollow tubular member extends from the lower region through the separation wall to the upper region, with its longitudinal axis substantially vertical. The lower portion of the hollow tube which is within the lower region is substantially full of a third fluid in its liquid state. The third fluid may be, for example, mercury. In operation, heat from the sodium would be transferred to the mercury which boils. The mercury vapor rises to the upper portion of the tube which is within the upper chamber. Heat is transferred from the mercury vapor to the water, heating and boiling the water while simultaneously condensing the mercury. The condensed mercury falls by gravity to the lower portion of the hollow tube where it is again heated by the sodium. Vapor from the boiling water may be transferred to a second chamber and superheated in a similar manner.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is illustrated in the drawings, of which:

FIG. 1 is a cross-sectional view of the heat exchanger elements of this invention.

FIG. 2 is a cross-sectional view of a heat exchanger having separate boiling and superheating chambers.

FIGS. 3 and 4 are cross-sectional views of another embodiment of heat exchangers having separate boiling and superheating chambers.

FIG. 5 is a schematic showing the heat transfer path of prior art shell and tube heat exchangers.

FIG. 6 is a schematic showing the heat transfer path in the heat exchanger of this invention.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 is a schematic representation of a cross section of the cylindrical thermal convection tube of this invention. Heat from a primary fluid 14, which may be, for example, sodium, is transferred to the working fluid 19 inside of the tube 10, causing the working fluid 19 to boil. The vapor 19A rises into the condenser section 11 of tube 10 where heat is removed to a secondary fluid 16, for example, water, thus condensing the working fluid 19. Gravitational forces cause the condensed working fluid 19B to return to the heater section 13 of tube 10. A downcomer 20 is used to promote the natural circulation of the working fluid and thus increase the efficiency of the system. A wall 17 separates the primary fluid 14 from the secondary fluid 16. Wall 17 can be made as thick as is required by strength and shielding considerations without significantly affecting the heat transfer through the thermal convection tube 10.

The axial temperature of the working fluid 19 in the thermal convection tube 10 varies only a few degrees from the saturation temperature at the liquid-vapor interface. This tube, like a heat pipe, represents a method of sustaining large heat fluxes over significant distances at nearly isothermal conditions. However, in the case of the thermal convection tube, the absence of a wick material permits the heat flux per unit area to be greatly increased over the normal heat pipe by allowing for boiling of the working fluid without decreasing tube lifetime.

FIG. 2 illustrates a thermal convection tube steam generator which may, for example, use sodium as the primary fluid and water as the secondary fluid. However, the invention is not restricted to use of these two fluids. The primary fluid enters through inlet 21, circulates past tube 38 in chamber 22, tube 34 in chamber 23 and tube 31 in chamber 24. The fluid exits through outlet 25. As the primary fluid moves past each of the tubes, heat is transferred to the working fluid within the tube. In the upper portion of the steam generator, a secondary fluid such as water in the liquid state enters through inlet 28 into section 29. Heat from the working fluid within tube 31 is transferred to the water in section 29, causing the water to boil. The vapors are carried into section 33 where heat from tube 34 acts to superheat the vapor. The vapor is then transferred to section 37 where additional superheating takes place by the transfer of heat from thermal tube 38. The superheated vapor exits through outlet 39. Separation of the stages allows the water to be boiled most efficiently in the nucleate boiling region in the boiler stage and then superheated in separate stages.

FIGS. 3 and 4 show a steam generator in which the tubes and stages are concentrically arranged. The primary fluid enters through inlets 42 and 43 in the lower portion of the generator and flows past thermal tubes 59 and 55 in sections 45 and 46. The primary fluid then flows into the center chamber 47, circulates past tubes 51 and is removed through outlet 49. Water enters through an inlet (not shown) into the upper chamber 52, where heat from tubes 51 causes the water to boil, generating steam. The steam flows radially to the inlet to chamber 53 where it is heated by heat transferred from

tubes 55. The superheated steam flows radially into chamber 58, where it is superheated to higher temperatures by heat transferred from tubes 59. The superheated steam exhausts through outlets 61 and 62.

Referring to FIG. 5, there is shown the heat path from the primary sodium 65 to water 66 in the prior art single-pass shell and tube steam generation system. The path is through the secondary sodium 68 and through tube walls 69 and 71.

Referring to FIG. 6, there are shown two paths of heat transfer from primary sodium 73 to the water 74 in the thermal convection system. One path is through the working fluid 76, which may be, for example, mercury, plus two tube walls 78 and 79. This heat path is the same as the heat path in the shell and tube system with the secondary sodium replaced by the working fluid 76. The second path is from the primary sodium 73 through the separation wall 80 (17 in FIG. 1). The thickness of the separation wall 80 may be very large without significantly reducing the performance of the thermal convection tube; most of the heat transfer occurs through the thermal convection tube. The working fluid 76 takes the place of the secondary sodium of the conventional system and thus an intermediate heat exchanger is not required. Further, the water is not immediately adjacent the sodium, so that the problems associated with sodium-water leaks are not present.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A heat exchanger system for use in generating steam with heat from a sodium fluid which has been heated in a nuclear reactor, including in combination, a first chamber coupled to the reactor for receiving said sodium fluid therefrom, said first

chamber having a top wall, a second chamber positioned above said first chamber with said top wall of said first chamber forming the bottom wall of said second chamber, said top and bottom wall forming a separation wall between said top and bottom chambers, said second chamber further containing water, a plurality of sealed hollow members each having an upper portion and a lower portion, each of said sealed hollow members being placed in a substantially vertical position and extending through said separation wall with said lower portion in said first chamber and said upper portion in said second chamber, said sealed hollow members being mechanically secured to said separation wall at the middle portion of said sealed hollow members, each of said sealed hollow members being in the form of a first tube having sides and closed bottom and top ends, with said lower portion thereof being substantially filled with liquid mercury, a second tube having open top and bottom ends and centrally located with reference to said sides of said first tube, said bottom end of said second tube being spaced away from said bottom end of said first tube, said top end of said second tube being positioned below the surface of said liquid mercury in said lower portion of said sealed hollow member, said heated sodium acting to heat said liquid mercury to form a mercury gas, said mercury gas rising to said upper portion and transferring heat to said water while in said upper portion to generate steam in said second chamber, said gas condensing to liquid mercury after said heat transfer and returning to said lower portion, said second tube acting as a downcomer to promote circulation of said liquid mercury in said lower portion.

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