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(54) **Heat exchanger**

(57) In a heat exchanger wherein a first fluid in a shell 11 is in heat exchange with a second fluid flowing through tubes 22 positioned in said shell, the tube ends pass through a thick tube sheet 14 and open into a header compartment 15 installed on that side of the tube sheet remote from said shell, the fluid inlet ends 22*a* of said tubes opening into a separate section 19 of said header compartment separated by a clearance from the tube sheet 14; and the inlet and outlet end portions (*h, l*) of said tubes being positioned alternately across the tube sheet 14 (e.g. as in Fig. 4*a*). By the provision of the separate section and alternate positioning of inlets and outlets of tubes, thermal stress arising in the thick tube sheet is made very small.

FIG. 2

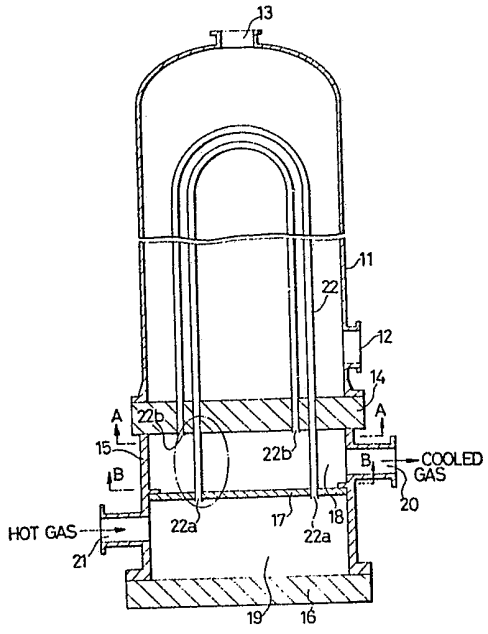

FIG. 4a

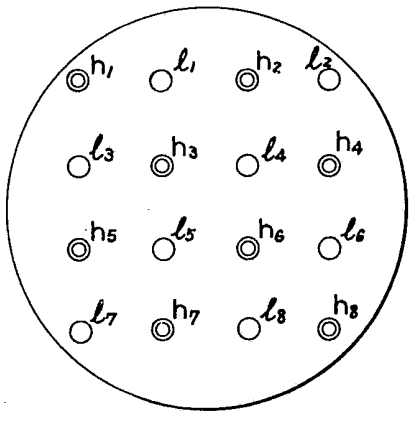

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FIG. 1a

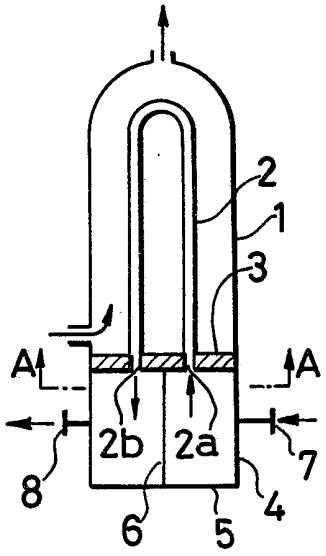


FIG. 1b

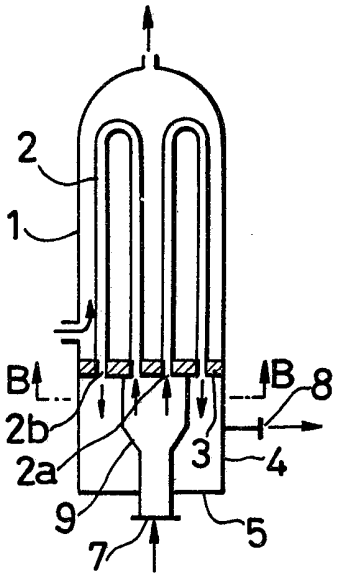


FIG. 1a'

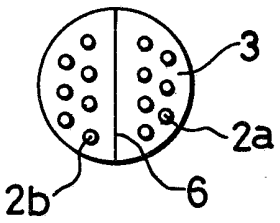


FIG. 1b'

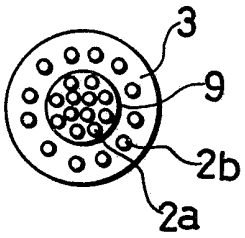


FIG. 1a''

FIG. 1b''

FIG. 2

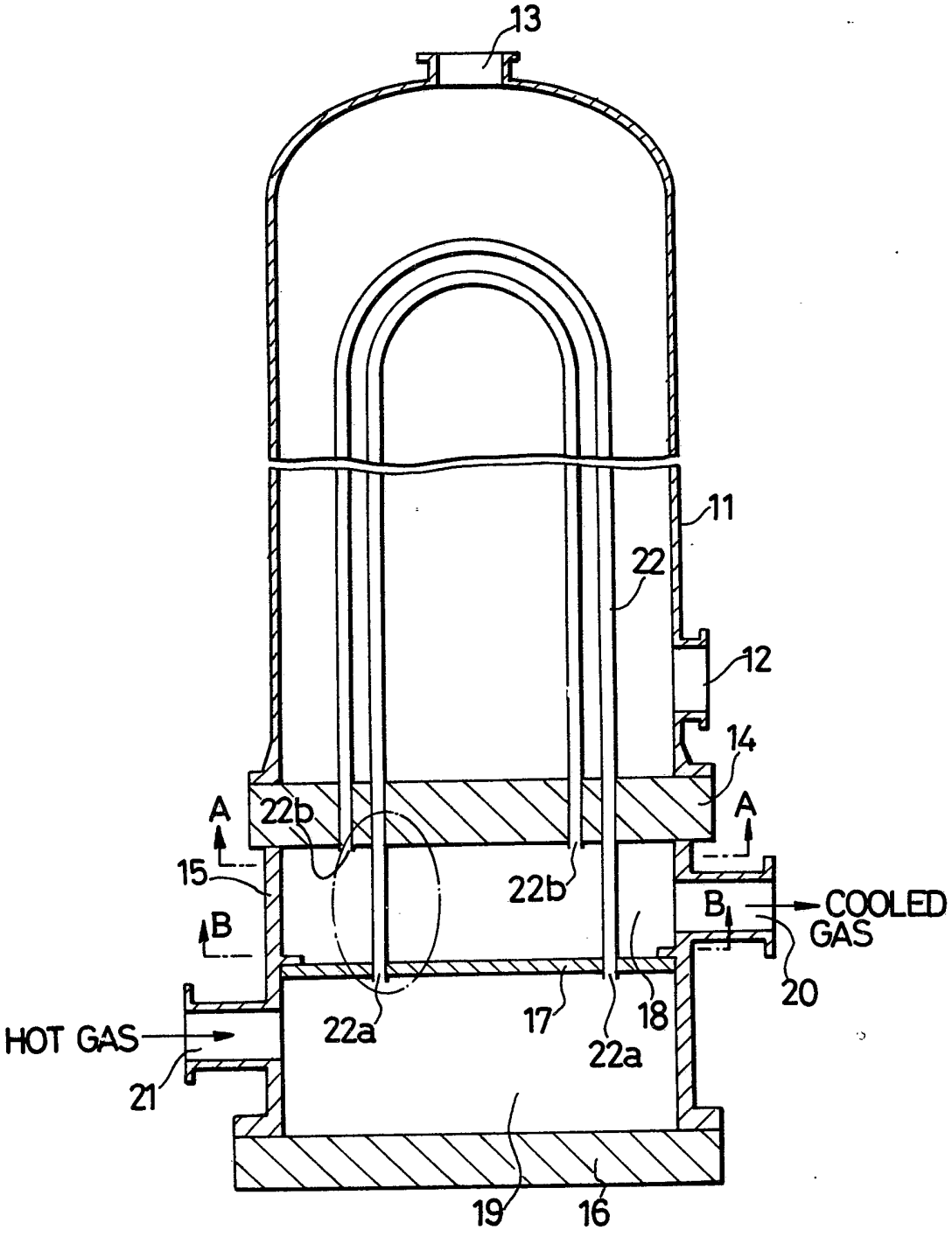

13
11
22
12
14
A
22b
A
15
22b
B
B
COOLED
GAS
20
HOT GAS
22a
17
18
22a
21
19
16

FIG. 4a

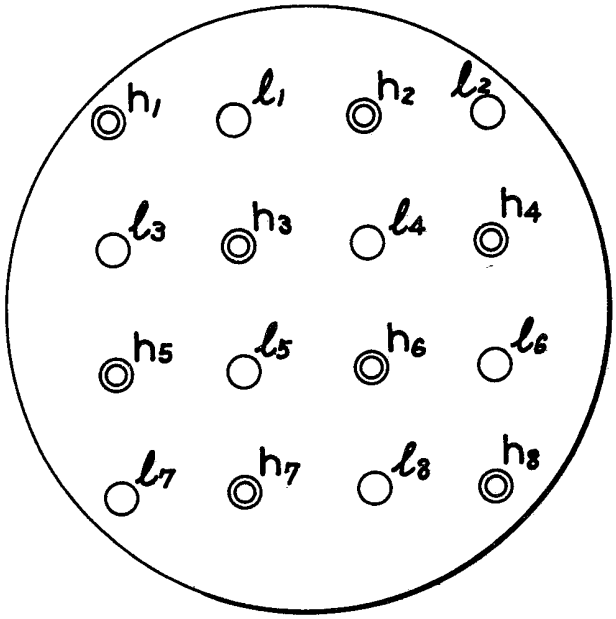


FIG. 4b

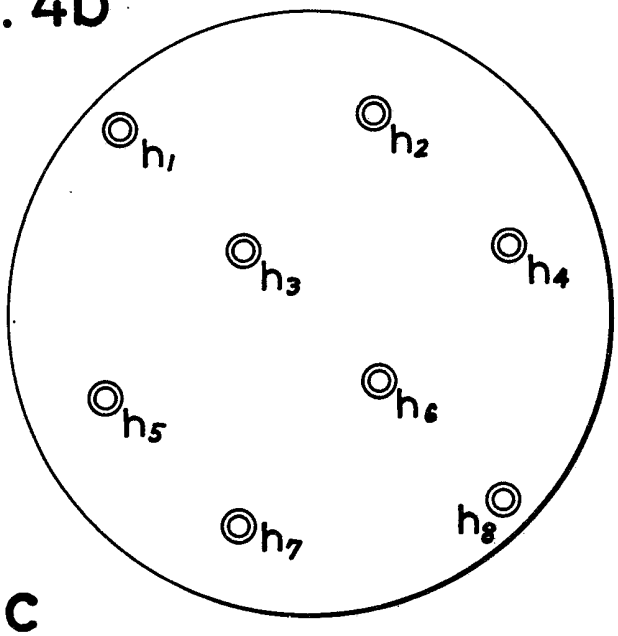


FIG. 4c

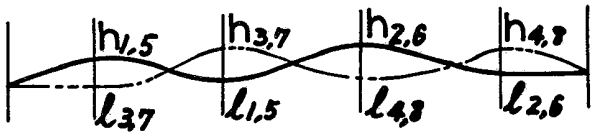


FIG. 5a

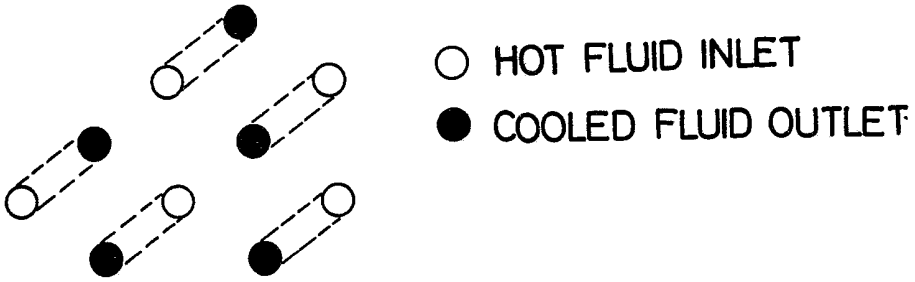


FIG. 5b

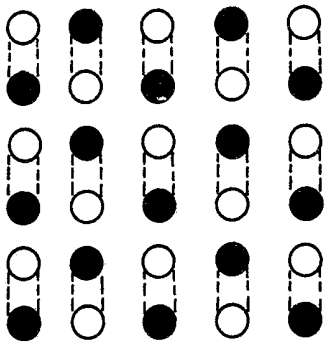


FIG. 6

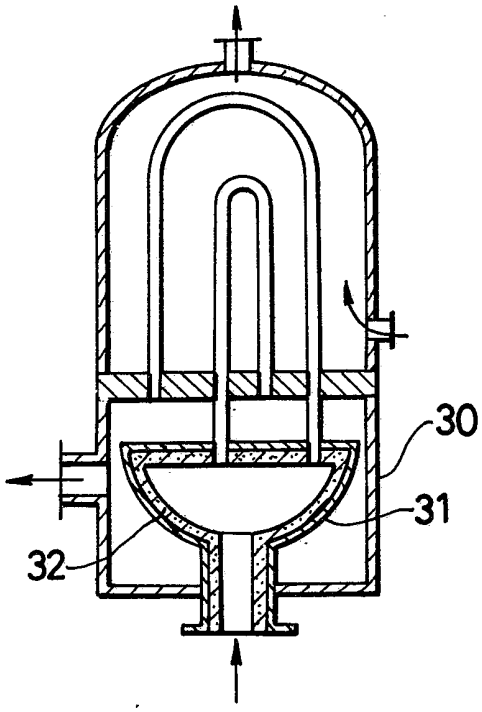
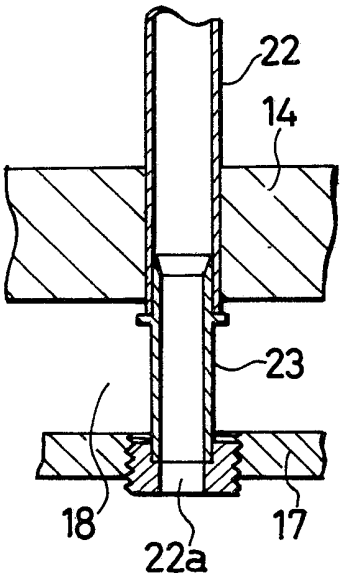


FIG. 3



SPECIFICATION

Heat exchanger

The present invention relates to heat exchangers for high temperature and high pressure service, in which temperature gradient in a thick tube sheet is descreased and thermal stress caused thereby is reduced accordingly, more particularly to heat exchangers, in which hot fluid before being heat exchanged is avoided from directly contacting a thick tube sheet, said hot fluid being introduced from a separated section through a group of tubes into a heat exchanger shell and let out through a fluid outlet nozzle opened at the tube sheet, with groups of those tubes for fluid before and after heat exchange being alternately arranged, resulting in large reduction of thermal stress arising in the thick tube sheet.

Generally, heat exchangers are used to recover heat from or exchange heat with hot gas generated by burning, chemical reaction or the like in chemical and various other industrial plants.

Conventionally, various types of heat exchangers are used, one of which is the U-tube type heat exchanger. The heat exchanger of this type is superior to others in that thermal stress is minimised, which stress is caused by different thermal expansion induced by temperature difference between tubes and a shell.

The heat exchangers of the U-tube type being conventionally used are shown in Figs. 1 (a), (a'), (b) and (b'). Fig. 1(a) is a schematic section of an example of conventional U-tube heat exchangers, wherein U-tubes 2 are arranged in a shell 1 having inlet and outlet nozzles for the first fluid, a tube sheet being secured to the bottom end of the shell 1, the ends 2*a*, 2*b* of the U-tubes passing through and being secured to the tube sheet 3, opened to the outside of the shell. On the side of the tube sheet 3 opposite to the shell 1 is provided a channel enclosed by a stationary head 4 and a channel cover 5, the channel being divided into two chambers by a pass partition 6. One of the two chambers is provided with an inlet nozzle 7 for the second fluid and the other chamber is provided with an outlet nozzle 8 for the second fluid, the ends 2*a* of the U-tubes 2 to admit the second fluid being altogether opened to one chamber and the other ends 2*b* of the U-tubes to discharge the second fluid being altogether opened to the other chamber. Fig. 1(a') shows the section along line A—A in Fig. 1(a).

Fig. 1(b) is a schematic section of another example of conventional U-tube type heat exchangers. This type comprises, similarly to the one in Fig. 1(a), a shell 1 in which U-tubes 2 are contained, and a channel enclosed by a stationary head 4 and a channel cover 5. In the channel an inner channel 9 having an inlet nozzle 7 for the second fluid is provided, the ends 2*a* of U-tubes to let in the second fluid being opened at the tube sheet of the inner channel 9 and the other ends of U-tubes to let out the second fluid being opened in the annular portion of the tube sheet between the inner channel 9 and the stationary head 4. Fig. 1(b') shows the section along line B—B in Fig. 1(b).

In the operation of the type of heat exchanger shown in Fig. 1(a), hot second fluid enters from the inlet nozzle 7 for the second fluid into the channel and flows further through the ends 2*a* of U-tubes into the U-tubes 2, and after exchanging heat with the first fluid in the shell 1, flows, through the channel, out from the outlet nozzle 8. Since the channel is divided into two chambers by the pass partition 6, the channel of the inlet side of the second fluid is filled with hot second fluid, making the tube sheet hot.

The channel of the outlet side of the second fluid is filled with cold second fluid, making that portion of the tube sheet 3 colder than the inlet side. The temperature distribution in the tube sheet 3 becomes asymmetric as shown in Fig. 1(a"), inducing large thermal stress and causes the designing of the heat exchanger difficult.

In the operation of the type of heat exchanger shown in Fig. 1(b), hot second fluid enters from the inlet nozzle 7 into the inner channel 9, flows through the inlet ports 2*a* of U-tubes into the U-tubes 2, and after exchanging heat with the first fluid in the shell 1 and being cooled, flows out from the outlet ports 2*b* of U-tubes into the annular space surrounding the inner channel 9, and then leaves the device through the outlet nozzle 8. In this case, the inside of the inner channel 9 is filled with hot second fluid, so the tube sheet 3 contacting with the hot fluid becomes hot, but on the other hand, the tube sheet portion outside the inner channel 9 contacts with cold second fluid after heat exchange and is made cold and therefore, the temperature distribution in the tube sheet is made as shown in Fig. 1(b"), the central portion being high and the peripheral portion being low. This difference in the temperature induces thermal stress in the tube sheet 3. The stress in this case is a little smaller than the case in Fig. 1(a), but still it is difficult to determine the arrangement of U-tubes for the case in Fig. 1(b).

The object of the present invention is to provide improved heat exchangers by obviating or mitigating the aforementioned problems associated with the U-tube type heat exchanger, more particularly by minimizing thermal stress arising in the tube sheet.

The present invention is a heat exchanger comprising a shell for containing a first fluid, tubes provided in said shell for passing second fluid for exchanging heat with said first fluid, and a tube sheet, and in which a chamber provided with an outlet port and an inlet port for said second fluid is installed on the side of said tube sheet opposite said shell, and tube outlet ends for said second fluid after exchanging heat pass through said tube sheet and open into said chamber, said chamber containing a separate section spaced from said tube sheet, said separate section being provided with an inlet port for said second fluid and inlets of the tubes which pass through said tube sheet and

are arranged in said shell, inlet ports of a hot side and outlet ports of a cold side of U-tubes being alternately positioned at said tube sheet to minimize thermal stress is said tube sheet.

Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:—

Figs. 1 (a) and (b) are schematic vertical sections of conventional U-tube type heat exchangers, (a') is a section along line A—A in Fig. 1(a), (b') is a section along line B—B in Fig. 1(b), and (a") and (b") are temperature distribution curves in respective tube sheet;

Fig. 2 is a schematic vertical section of a heat exchanger according to the invention;

Fig. 3 is a detail schematic section of the region where the tube end is attached to the tube sheet;

Fig. 4(a) is a section along line A—A in Fig. 2, (b) is a section along line B—B, and (c) is a temperature distribution chart of the tube sheet of the heat exchanger in Fig. 2;

Figs. 5(a), (b) are a schematic view of tubing of another embodiment of the invention; and

Fig. 6 is a schematic vertical section of still another embodiment of the invention.

Fig. 2 is a schematic section of an embodiment of heat exchangers according to the invention, wherein a shell 11 has an inlet nozzle 12 and outlet nozzle 13 for first fluid, a tube sheet 14 being secured to the bottom portion. A stationary head 15 is secured to the side of the tube sheet 14 opposite the shell 11, the lower end of the stationary head 15 being covered by a chamber cover 16 and a separated chamber being defined by the stationary head 15, chamber cover 16 and tube sheet 14. The chamber is divided into two compartments 18, 19 by a pass partition 17. The upper compartment 18 is provided with an outlet nozzle 20 for the second fluid and the lower compartment 19 with an inlet nozzle 21 for the second fluid. A plurality of U-tubes 22 are arranged in the shell 11, one end of each of the U-tubes being opened at the lower surface of the pass partition 17 and communicating with the lower compartment 19 of the chamber, and the other end of each of the U-tubes being opened at the lower surface of the tube sheet 14 and communicating with the upper compartment 18 of the chamber.

Fig. 3 is a schematic section showing how to secure the tube end to the pass partition 17. As shown in the Figure, the tube end of the U-tube is secured to the tube sheet 14 and a separate straight tube 23 is connected to the tube end using a tube expansion technique or the like, extended through the upper compartment 18 of the chamber and secured to the pass partition 17 with a hollow screw or the like.

Figs. 4 (a), (b) show the sections along lines A—A and B—B in Fig. 2, h_1-h_8 representing the inlet ends of the tubes for the second fluid and l_1-l_8 representing the outlet ends of the tubes for the second fluid. Thus, the tubes h and l are alternately arranged, the tubes h_1 and l_2 communicate with each other and the tubes l_1 and h_2 communicate with each other, respectively, in the upper part of the shell 11.

In the operation of the above embodiment of a heat exchanger according to the invention, the first fluid enters from the inlet nozzle 12 into the shell 11 and after exchanging heat with the second fluid and upon being heated, leaves the device from the outlet nozzle 13. On the other hand, hot second fluid enters from the inlet nozzle 21, which is in the chamber lower compartment 19, into the channel lower compartment 19, flows through the inlet ports 22*a* of the U-tubes, which are opened at the pass partition 17, into the U-tubes and after exchanging heat at the U-tube portion 22 with first fluid and being cooled down, goes through the outlet ports 22*b* of the U-tubes, which are opened at the tube sheet 14, into the chamber upper compartment 18 and leaves the device through the outlet nozzle 20.

In this case, the tube sheet 14 comes in contact with cold second fluid which is cooled after exchanging heat with the first fluid, but not directly with hot second fluid. The temperature distribution in the tube sheet 14 is as shown in Fig. 4(c), the portion contacting with the inlet ports h_1-h_8 of the U-tubes being heated and the portion contacting the outlet ports l_1-l_8 of the U-tubes being cooled, but the temperature difference therebetween is smaller than the conventional ones shown in Figs. 1(a") and (b"), the curve being relatively flat. Therefore, thermal stress arising in the tube sheet 14 is very small.

The U-tubes can be arranged in such a manner as shown in Figs. 5(a) and (b), wherein the inlet side portion of each of the tubes is located adjacent to the outlet side portion thereof by making the curvature of the curved portion of the U-tubes small.

Fig. 6 is a schematic section of another embodiment of a heat exchanger according to the invention. In this embodiment, an inner chamber compartment 31 is provided in the chamber 30 and hot second fluid enters the inner compartment 31 and after exchanging heat through the U-tubes and being cooled, flows into the space outside the inner compartment 31 and leaves the device through the outlet nozzle. The internal surface of the inner compartment 31 is preferably lined with thermal insulation material. This permits the use of non-heat resisting steel for the wall material of the inner compartment 31, since the outside surface of the compartment 31 does not come in direct contact with hot second fluid, and the compartment 30 also is not exposed to hot second fluid, and therefore, the design of and material selection for heat exchangers can be made on a low temperature basis.

The above embodiments are described using U-tube type heat exchangers, but the construction according to the invention, wherein a channel for admitting hot second fluid is separated to prevent hot second fluid from directly contacting a thick tube sheet, can be applied to other heat exchangers other than U-tube type heat exchangers, the other heat exchangers being

included within the scope of the invention.

CLAIMS

1. A heat exchanger comprising a shell for containing a first fluid, tubes provided in said shell for passing second fluid for exchanging heat with said first fluid, and a tube sheet, and in which a chamber provided with an outlet port and an inlet port for said second fluid is installed on the side of said tube sheet opposite said shell, and tube outlet ends for said second fluid after exchanging heat pass through said tube sheet and open into said chamber, said chamber containing a separate section spaced from said tube sheet, said separate section being provided with an inlet port for said second fluid and inlets of the tubes which pass through said tube sheet and are arranged in said shell, inlet ports of a hot side and outlet ports of a cold side of U-tubes being alternately positioned at said tube sheet to minimise thermal stress in said tube sheet.

2. A heat exchanger as claimed in claim 1, in which said chamber is divided by a pass partition to form the separate section.

3. A heat exchanger as claimed in claim 1, in which said chamber contains an inner compartment to form the separate section.

4. A heat exchanger as claimed in any preceding claim, in which U-tubes are used for said tubes to admit second fluid therein.

5. A heat exchanger as claimed in any preceding claim, in which the inlet section and outlet section of each of said U-tubes are positioned adjacent to each other by making the curvature of the curved portion of U-tubes small.

6. A heat exchanger as claimed in any preceding claim, in which all or part of said channel and said separate section are covered by thermal insulation materials.

7. A heat exchanger substantially as hereinbefore described with reference to, and as shown in, Figs. 2 to 6 of the accompanying drawings.

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