A multipass tubular heat exchanger utilizing a pass partition plate and a tubesheet is described which is suitable for use with high differential pressure tubeside fluid without deformation or dislocation of the pass partition plate, thereby avoiding the problem of tubeside fluid bypassing. The pass partition plate has an edge fitting into a corresponding groove in the tubesheet. The edge and the corresponding groove each have a radius of curvature about an axis extending generally perpendicular to the tubesheet.
MULTIPASS TUBULAR HEAT EXCHANGER
AND ASSOCIATED PASS PARTITION PLATE,
CHANNEL COVER, AND METHODS

FIELD

[0001] The present disclosure relates generally to multipass tubular heat exchangers, more particularly to multipass tubular heat exchangers having tubesheets and pass partition plates.

BACKGROUND

[0002] Multipass tubular heat exchangers which exchange heat from one fluid to another without mixing the fluids are widely used in a variety of sizes, configurations and applications. Heat is exchanged by flowing a first heat exchange fluid referred to as the tubeside fluid within a plurality of tubes surrounded by a second heat exchange fluid. The tubeside fluid traverses the length of the tubes multiple times. At one or both ends of the plurality of tubes is a cover enclosing a space in fluid communication with the tubes, which is commonly referred to by a variety of terms such as a channel, bonnet, header box, or head, depending on the particular type of heat exchanger and application. Between the enclosed space and the tubes is a planar tubesheet with holes for receiving the ends of the tubes. In order to direct the tubeside fluid through the tubes in the desired multiple passes, a pass partition plate is typically provided within the enclosed space(s). Typically the plate is welded within the cover, and the cover with the plate is structurally secured to the rest of the heat exchanger so that the plate is held firmly against the tubesheet. A gasket is typically included between the plate and the tubesheet, creating a seal so that tubeside fluid cannot bypass the tubes. In other words, fluid entering an inlet side of the enclosed space is directed through the tubes before flowing into an outlet side of the enclosed space.

[0003] In operation, the fluid pressure on the inlet side exceeds the pressure on the outlet side. This differential pressure, also referred to as the interpass pressure, exerts a force on the pass partition plate which acts to push the partition plate in the direction of the lower pressure outlet side. The interpass pressure generally increases over time as fouling or tube plugging occurs. On occasion this pressure is sufficient to cause the plate to deform and to break contact with the tubesheet. This can have several detrimental effects. For one, once contact between the partition plate and the tubesheet is broken, the tubeside fluid is permitted to bypass the tubes, thus decreasing the flow and the amount of heat exchange accomplished by the exchanger. Another potential problem when the plate breaks contact with the tubesheet is that the plate may scrape against the ends of the tubes, breaking the seal between the tubes and the tubesheet and thus introducing opportunities for mixing of the heat exchange fluids. These problems often require plant shutdowns for repairs, including reshaping or replacing the pass partition plate.

SUMMARY

[0004] It would be desirable to have a multipass tubular heat exchanger which would reduce the likelihood of the aforementioned problems.

[0005] One embodiment of the invention relates to a multipass tubular heat exchanger comprising:

[0006] a plurality of tubes configured to contain a tubeside fluid, the plurality of tubes having at least one set of terminal ends;

[0007] a planar tubesheet comprising apertures for receiving the ends of the tubes and a groove for receiving a pass partition plate, the groove having a length, a thickness, two endpoints and a midpoint;

[0008] a channel having a tubeside fluid inlet and a tubeside fluid outlet, the channel positioned adjacent the tubesheet such that the channel and tubesheet together define an internal space in fluid communication with the tubes; and

[0009] a nonplanar pass partition plate positioned in the internal space configured to divide the internal space into an inlet space in fluid communication with the tubeside fluid inlet and an outlet space in fluid communication with the tubeside fluid outlet, thereby to prevent direct fluid communication between the tubeside fluid inlet and the tubeside fluid outlet and to direct fluid flow through the tubes, wherein the pass partition plate has a mating edge which fits into the groove of the tubesheet;

[0010] wherein the groove of the tubesheet and the mating edge of the pass partition plate each have a radius of curvature about an axis extending generally perpendicular to the tubesheet such that the midpoint of the groove is a greater distance from a straight line passing through the endpoints of the groove than the thickness of the groove.

[0011] Another embodiment of the invention relates to a multipass tubular heat exchanger comprising:

[0012] a plurality of tubes configured to contain a tubeside fluid, the plurality of tubes having at least one set of terminal ends;

[0013] a planar tubesheet comprising apertures for receiving the ends of the tubes;

[0014] a channel having a tubeside fluid inlet and a tubeside fluid outlet, the channel positioned adjacent the tubesheet such that the channel and tubesheet together define an internal space in fluid communication with the tubes; and

[0015] a nonplanar pass partition plate positioned in the internal space configured to divide the internal space into an inlet space in fluid communication with the tubeside fluid inlet and an outlet space in fluid communication with the tubeside fluid outlet, thereby to prevent direct fluid communication between the tubeside fluid inlet and the tubeside fluid outlet and to direct fluid flow through the tubes;

[0016] wherein the pass partition plate has an edge which is fixed to the tubesheet, the edge having a radius of curvature about an axis extending generally perpendicular to the tubesheet.

[0017] Another embodiment of the invention relates to a matching pass partition plate and tubesheet for use in a multipass tubular heat exchanger comprising:

[0018] a planar tubesheet comprising apertures for receiving ends of heat exchanger tubes and a groove for receiving a pass partition plate, the groove having a length, a thickness, two endpoints and a midpoint;

[0019] a nonplanar pass partition plate having a mating edge which fits into the groove of the tubesheet;

[0020] wherein the groove of the tubesheet and the mating edge of the pass partition plate each have a radius of curvature about an axis extending generally perpendicular to the tubesheet such that the midpoint of the groove is a greater distance from a straight line passing through the endpoints of the groove than the thickness of the groove.

[0021] Another embodiment of the invention relates to a channel cover for use in a multipass tubular heat exchanger comprising:
[0022] a semi-enclosed channel having a planar open end and configured to define an internal space when the open end is positioned adjacent a planar tubesheet; and

[0023] a nonplanar pass partition plate having peripheral edges fixed within the channel and a free edge in the plane of the open end wherein the free edge has a radius of curvature about an axis extending generally perpendicular to the plane of the open end.

[0024] Another embodiment of the invention relates to a method of retrofitting a multipass tubular heat exchanger having an existing tubesheet and an existing pass partition plate, comprising:

[0025] removing the existing tubesheet and the existing pass partition plate;

[0026] installing a planar tubesheet comprising a plurality of apertures for receiving ends of heat exchanger tubes and a groove for receiving a pass partition plate; and

[0027] a nonplanar pass partition plate having a mating edge which fits into the groove of the tubesheet, wherein the groove of the tubesheet and the mating edge of the pass partition plate each have a radius of curvature about an axis extending generally perpendicular to the tubesheet.

[0028] Another embodiment of the invention relates to a method of exchanging heat between a tubsede fluid flowing through a plurality of tubes in a multipass tubular heat exchanger and a fluid surrounding the plurality of tubes, comprising:

[0029] introducing a tubsede fluid into an internal space defined by a channel and a planar tubesheet having a plurality of apertures, the internal space being in fluid communication with a plurality of tubes having a plurality of a tubsede fluid inlet ends aligned with a first portion of the plurality of apertures of the tubesheet and a plurality of tubsede fluid outlet ends aligned with a second portion of the plurality of apertures of the tubesheet; and

[0030] flowing the tubsede fluid into the plurality of tubes through the first portion of the plurality of apertures and through the plurality of tubes between the tubsede fluid inlet ends and the tubsede fluid outlet ends such that the tubsede fluid exits through the second portion of the plurality of apertures into the internal space;

[0031] wherein the tubsede fluid exiting the tubes is separated from the tubsede fluid entering the tubes by a nonplanar pass partition plate dividing the internal space having an edge in contact with the tubesheet which has a radius of curvature about an axis perpendicular to the tubesheet;

[0032] wherein no bypassing of tubsede fluid occurs around the pass partition plate.

BRIEF DESCRIPTION OF THE FIGURES

[0033] FIG. 1 is a perspective view of a heat exchanger according to the prior art.

[0034] FIG. 2 is an end view of a tubesheet for use in a heat exchanger according to one embodiment of the invention.

[0035] FIG. 2A is a section view partially illustrating the tubesheet of FIG. 2, as seen along line 2A-2A.

[0036] FIG. 3 is a perspective view of a combination of a matching pass partition plate and tubesheet according to one embodiment of the invention.

[0037] FIG. 4A is a diagrammatic end view of a tubesheet for use in heat exchangers according to the prior art, and FIGS. 4D-4D are diagrammatic end views of tubesheets for use in heat exchangers according to alternative embodiments of the invention.

[0038] FIG. 5A is a diagrammatic end view of a tubesheet for use in heat exchangers according to the prior art, and FIGS. 5B-5D are diagrammatic end views of tubesheets for use in heat exchangers according to additional alternative embodiments of the invention.

[0039] FIG. 6A is a diagrammatic end view of a tubesheet for use in heat exchangers according to the prior art, and FIGS. 6B-6D are diagrammatic end views of tubesheets for use in heat exchangers according to additional alternative embodiments of the invention.

[0040] FIG. 7A is a diagrammatic end view of a tubesheet for use in heat exchangers according to the prior art, and FIGS. 7B-7D are diagrammatic end views of tubesheets for use in heat exchangers according to additional alternative embodiments of the invention.

[0041] FIG. 8A is a diagrammatic end view of a tubesheet for use in heat exchangers according to the prior art, and FIGS. 8B-8D are diagrammatic end views of tubesheets for use in heat exchangers according to additional alternative embodiments of the invention.

[0042] FIG. 9A is a diagrammatic end view of a tubesheet for use in heat exchangers according to the prior art, and FIGS. 9B-9D are diagrammatic end views of tubesheets for use in heat exchangers according to additional alternative embodiments of the invention.

[0043] FIG. 10A is a diagrammatic end view of a tubesheet for use in heat exchangers according to the prior art, and FIGS. 10B-10D are diagrammatic end views of tubesheets for use in heat exchangers according to additional alternative embodiments of the invention.

[0044] FIG. 11A is a diagrammatic end view of a tubesheet for use in heat exchangers according to the prior art, and FIGS. 11B-11D are diagrammatic end views of tubesheets for use in heat exchangers according to additional alternative embodiments of the invention.

[0045] FIG. 12A is a diagrammatic end view of a tubesheet for use in heat exchangers according to the prior art, and FIGS. 12B-12D are diagrammatic end views of tubesheets for use in heat exchangers according to additional alternative embodiments of the invention.

DETAILED DESCRIPTION

[0046] FIG. 1 illustrates a multipass tubular heat exchanger 10 according to the prior art. The heat exchanger includes a plurality of tubes 4 for containing a heat exchange fluid referred to as a tubsede fluid. The plurality of tubes 4 has at least one set of coplanar terminal ends. The tubes of the heat exchanger can be U-shaped tubes, also referred to as U tubes, as illustrated in FIG. 1, having all terminal ends, i.e., both the tubsede fluid inlet and outlet ends, in a single plane. A heat exchanger utilizing U tubes is referred to herein as a U tube heat exchanger. Alternatively, the tubes may be straight, having inlet ends and outlet ends at opposite ends of the tubes. A heat exchanger utilizing straight tubes is referred to herein as a straight tube heat exchanger. At one or both ends of the plurality of tubes is an internal space in fluid communication with the tubes defined by a semi-enclosed cover and a tubesheet. The semi-enclosed cover is commonly referred to by a variety of terms such as channel, channel cover, bonnet, header box, head and floating head, depending on the particular type of heat exchanger and application. For the purposes of this disclosure, the term “channel” is used to refer to the semi-enclosed cover regardless of the specific type of heat exchanger. A U tube heat exchanger has a channel 8 at one end
of the plurality of tubes, as shown in FIG. 1. The channel includes a tubeside fluid inlet 8A and a tubeside fluid outlet 8B. A straight tube heat exchanger has a channel at each end of the plurality of tubes (not shown). Regardless of whether the heat exchanger utilizes U tubes or straight tubes, the ends of the tubes are received by apertures 5A in a planar tubesheet 5 located adjacent the channel between the channel and the plurality of tubes. The ends of the tubes are sealed to the tubesheet 5. The tubes may be supported by cross-flow baffles 13.

[0047] In a tubular heat exchanger, heat is exchanged by flowing a tubeside fluid within tubes in a plurality of tubes surrounded by a second heat exchange fluid. In a multipass tubular heat exchanger, the tubeside fluid traverses the length of the tubes multiple times. In order to direct the tubeside fluid through the tubes in the desired multiple passes and to prevent direct communication between the tubeside fluid inlet and the tubeside fluid outlet, it is common practice to include a pass partition plate 1 within the channel(s). Typically peripheral edges of the plate are welded within the channel, and the channel and plate are structurally secured to the shell 12 or other structure of the heat exchanger so that an edge of the plate is held firmly against the tubesheet. The pass partition plate has a mating edge 1A which fits into groove 5B of the tubesheet 5. This groove is typically 3-8 mm deep. Alloy or carbon steel is typically used as the material for the channel, the pass partition plate and the tubesheet. The pass partition plate divides the internal space within the channel into at least an inlet space in fluid communication with the tubeside fluid inlet and outlet space in fluid communication with the tubeside fluid outlet.

[0048] According to one embodiment of the present invention, the groove of the tubesheet and the mating edge of the pass partition plate each have a radius of curvature. FIG. 2 illustrates a tubesheet 6 for use in a heat exchanger according to one embodiment of the invention. Apertures 6A are provided for receiving the ends of heat exchanger tubes. At least one groove 6B is provided for receiving the edge of the pass partition plate. Unlike the prior art groove(s) which are in the form of straight lines, the groove according to the invention has a radius of curvature. Referring to FIG. 2, the distance 16 between the midpoint of groove 6B and an imaginary line 14 between the endpoints of groove 6B is greater than the thickness of groove 6B. Distance 16 may be greater than the length of line 14 divided by 100, even greater than the length of line 14 divided by 50. The desired amount of curvature and the direction of the curvature, i.e., in the direction of the tubeside fluid inlet or the direction of the tubeside fluid outlet, will vary depending on the particular mechanical design considerations and process design considerations for the intended application. Relevant design considerations may include the particular materials for use in the pass partition plate, channel and tubesheet, the particular heat exchange fluids being used, the use of pulsating fluid, operating temperature and pressure, and two-phase phenomena such as boiling and condensing. As illustrated in FIG. 2, the radius of curvature of the both the groove and pass partition plate is defined about an axis that extends generally perpendicular to the tubesheet, i.e., the radius of curvature is defined by the profile of the groove and plate when viewed in a direction perpendicular to the plane of the tubesheet.

[0049] According to one embodiment of the invention, a matching tubesheet and pass partition plate are provided, collectively denoted by reference numeral 20 in FIG. 3. Pass partition plate 2 has a radius of curvature along its mating edge 2A to correspond to the radius of curvature of the groove 6B, therefore the pass partition plate is nonplanar. The thickness of the pass partition plate will vary according to the particular design considerations of the intended application. In some cases, the pass partition plate and the groove can be curved to be concave when viewed from the direction of the tubeside fluid inlet, i.e., so that a positive differential pressure tends to flatten the pass partition plate. In other cases, the pass partition plate and the groove can be curved to be convex when viewed from the direction of the tubeside fluid inlet, i.e., so that a positive differential pressure tends to bend the pass partition plate to a greater curvature. While the present invention is not limited to any particular theory of operation, it is believed that a convexly or concavely curved pass partition plate can provide more stiffness compared to a flat pass partition plate of otherwise similar dimensions. Advantageously, because the plate has a radius of curvature and is therefore able to withstand greater differential pressure, a thinner plate may be possible than conventional flat plates. Alternatively, for an equivalent thickness plate, greater differential pressures can be tolerated during operation than using conventional flat plates.

[0050] As shown in FIGS. 2 and 2A, a gasket 22 is typically positioned immediately adjacent and between the channel and the tubesheet 6. The gasket may include a rib portion which acts as a gasket between the pass partition plate 2 and the groove 6B of the tubesheet, also referred to as a pass partition gasket. The material used for the gasket and the rib can be any suitable material for the application such as, but not limited to, metal, paper board, composite material, elastomeric material, and the like.

[0051] Multipass tubular heat exchangers which exchange heat from one fluid to another without mixing the fluids are widely used in a variety of sizes, configurations and applications. Heat exchangers utilizing the features of the embodiments disclosed herein are not limited in these regards and are likewise useful in a wide variety of sizes, configurations and applications.

[0052] According to one embodiment, the heat exchanger is a shell and tube heat exchanger. FIG. 1 illustrates a typical shell and tube heat exchanger wherein the tubes are housed within a shell 12 for containing a shell fluid, the shell having a shell fluid inlet 12A and a shell fluid outlet 12B. The tubesheet 6 is secured to one end of the shell 12.

[0053] According to an alternative embodiment, the heat exchanger is an air cooled heat exchanger which does not include a shell, in which heat is exchanged between the tube fluid within the tubes and air moving over the tubes. Typically in an air cooled heat exchanger, the pass partition plate is fixed within the channel cover and also fixed to the tubesheet rather than fitted into a groove as described above. The plate may be fixed to the tubesheet via welding or may be otherwise formed integrally with the tubesheet.

[0054] The heat exchanger may have a floating tubesheet and floating head, as are known to those of ordinary skill in the art.

[0055] FIGS. 4-12 illustrate nonlimiting examples of additional shapes (end view profiles) of pass partition plate which may be used to partition the channel, according to the prior art as well as to the present invention. In each of FIGS. 4-12, the “A” view illustrates the end view profile of the pass partition plate(s) known in the prior art. The “B” through “D” views illustrate nonlimiting examples of various end view profiles
of pass partition plates according to the present invention, in which curvature has been introduced to the corresponding prior art profile.

[0056] As can be seen from these figures, multiple pass partition plates and multiple grooves may be present in a given tubesheet. Many passes of tubeside fluid through the multipass tubular heat exchanger are possible according to the present disclosure.

[0057] According to one embodiment of the invention, a method is provided for exchanging heat between a tubeside fluid and a fluid surrounding the heat exchanger tubes. Tubeside fluid is introduced into the internal space defined by the channel and planar tubesheet and flows through a portion of the apertures in the tubesheet and through the corresponding tubes. The tubeside fluid exits through a second portion of the apertures in the tubesheet back into the internal space. The tubeside fluid exiting the tubes is separated from the tubeside fluid entering the tubes by the nonplanar pass partition plate dividing the internal space having an edge in contact with the tubesheet which has a radius of curvature about an axis perpendicular to the tubesheet. Advantageously, the method can be run with high differential pressure or multipass pressure, and no bypassing of tubeside fluid occurs around the pass partition plate.

[0058] According to another embodiment of the invention, a method is provided for retrofitting an existing multipass tubular heat exchanger. This method is particularly appropriate to repair heat exchangers in which the pass partition plate has already been damaged by high differential pressure use, or to make a conventional heat exchanger suitable for high differential pressure use. According to this method, the existing tubesheet and existing pass partition plate are removed from the heat exchanger and replaced with a curved pass partition plate as described herein and corresponding tubesheet. According to one embodiment of the invention, the curved pass partition plate and corresponding tubesheet are provided as a matched set. According to another embodiment of the invention, a semi-enclosed channel cover is conveniently provided in which the nonplanar pass partition plate is fixed within the channel and the free edge of the pass partition plate is curved.

What is claimed is:

1. A multipass tubular heat exchanger comprising:
   a plurality of tubes configured to contain a tubeside fluid,
   the plurality of tubes having at least one set of terminal ends;
   a planar tubesheet comprising a plurality of apertures for receiving the ends of the tubes;
   a channel having a tubeside fluid inlet and a tubeside fluid outlet, the channel positioned adjacent the tubesheet such that the channel and tubesheet together define an internal space in fluid communication with the tubes;
   a nonplanar pass partition plate positioned in the internal space configured to divide the internal space into an inlet space in fluid communication with the tubeside fluid inlet and an outlet space in fluid communication with the tubeside fluid outlet, thereby preventing direct fluid communication between the tubeside fluid inlet and the tubeside fluid outlet and to direct fluid flow through the tubes;
   wherein the partition plate has an edge which is fixed to the tubesheet, the edge having a radius of curvature about an axis extending generally perpendicular to the tubesheet.

2. The multipass tubular heat exchanger of claim 1 wherein the planar tubesheet further comprises
   a groove for receiving the pass partition plate, the groove having a length, a thickness, two endpoints and a midpoint;
   and wherein the pass partition plate further comprises a mating edge which fits into the groove of the tubesheet;
   wherein the groove of the tubesheet and the mating edge of the pass partition plate each have a radius of curvature about an axis extending generally perpendicular to the tubesheet such that the midpoint of the groove is a greater distance from a straight line passing through the endpoints of the groove than the thickness of the groove.

3. The multipass tubular heat exchanger of claim 1 further comprising:
   a shell enclosing the plurality of tubes for containing a shell fluid, the shell having a first end and a second end and having a shell fluid inlet and a shell fluid outlet;
   wherein the shell is secured to the first end of the shell.

4. The multipass tubular heat exchanger of claim 1 further comprising a gasket between the channel and the tubesheet.

5. The multipass tubular heat exchanger of claim 4 wherein the gasket includes a rib portion adjacent and between the pass partition plate and the groove of the tubesheet.

6. The multipass tubular heat exchanger of claim 1 wherein the midpoint of the groove is a greater distance from a straight line passing through the endpoints of the groove than the distance between the endpoints of the groove divided by 100.

7. The multipass tubular heat exchanger of claim 1 wherein the heat exchanger is an air cooled heat exchanger in which heat is exchanged between the tubeside fluid within the plurality of tubes and air moving over the plurality of tubes.

8. The multipass tubular heat exchanger of claim 1 wherein the plurality of tubes comprise straight tubes having openings on each end received by apertures in a tubesheet on each end in fluid communication with a channel on each end adjacent the tubesheet.

9. The multipass tubular heat exchanger of claim 1 wherein the plurality of tubes comprise U-shaped tubes.

10. The multipass tubular heat exchanger of claim 1 comprising multiple pass partition plates.

11. The multipass tubular heat exchanger of claim 1 comprising multiple grooves.

12. The multipass tubular heat exchanger of claim 1 wherein the radius of curvature is in the direction of the tubeside fluid inlet.

13. The multipass tubular heat exchanger of claim 1 wherein the radius of curvature is in the direction of the tubeside fluid outlet.

14. A matching pass partition plate and tubesheet for use in a multipass tubular heat exchanger comprising:
   a planar tubesheet comprising apertures for receiving ends of heat exchanger tubes and a groove for receiving a pass partition plate, the groove having a length, a thickness, two endpoints and a midpoint;
   a nonplanar pass partition plate having a mating edge which fits into the groove of the tubesheet;
   wherein the groove of the tubesheet and the mating edge of the pass partition plate each have a radius of curvature about an axis extending generally perpendicular to the tubesheet such that the midpoint of the groove is a
greater distance from a straight line passing through the endpoints of the groove than the thickness of the groove.

15. A channel cover for use in a multipass tubular heat exchanger comprising:
a semi-enclosed channel having a planar open end and configured to define an internal space when the open end is positioned adjacent a planar tubesheet; and
a nonplanar pass partition plate having peripheral edges fixed within the channel and a free edge in the plane of the open end wherein the free edge has a radius of curvature about an axis extending generally perpendicular to the plane of the open end.

16. A method of retrofitting a multipass tubular heat exchanger having an existing tubesheet and an existing pass partition plate, comprising:
removing the existing tubesheet and the existing pass partition plate;
installing a planar tubesheet comprising a plurality of apertures for receiving ends of heat exchanger tubes and a groove for receiving a pass partition plate; and
a nonplanar pass partition plate having a mating edge which fits into the groove of the tubesheet;
wherein the groove of the tubesheet and the mating edge of the pass partition plate each have a radius of curvature about an axis extending generally perpendicular to the tubesheet.

17. A method of exchanging heat between a tubeside fluid flowing through a plurality of tubes in a multipass tubular heat exchanger and a fluid surrounding the plurality of tubes, comprising:
introducing a tubeside fluid into an internal space defined by a channel and a planar tubesheet having a plurality of apertures, the internal space being in fluid communication with a plurality of tubes having a plurality of a tubeside fluid inlet ends aligned with a first portion of the plurality of apertures of the tubesheet and a plurality of tubeside fluid outlet ends aligned with a second portion of the plurality of apertures of the tubesheet; and
flowing the tubeside fluid into the plurality of tubes through the first portion of the plurality of apertures and through the plurality of tubes between the tubeside fluid inlet ends and the tubeside fluid outlet ends such that the tubeside fluid exits through the second portion of the plurality of apertures into the internal space;
wherein the tubeside fluid exiting the tubes is separated from the tubeside fluid entering the tubes by a nonplanar pass partition plate dividing the internal space having an edge in contact with the tubesheet which has a radius of curvature about an axis perpendicular to the tubesheet;
wherein no bypassing of tubeside fluid occurs around the pass partition plate.

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