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HEAT EXCHANGER TUBE SHEET THERMAL SHIELD CONSTRUCTION

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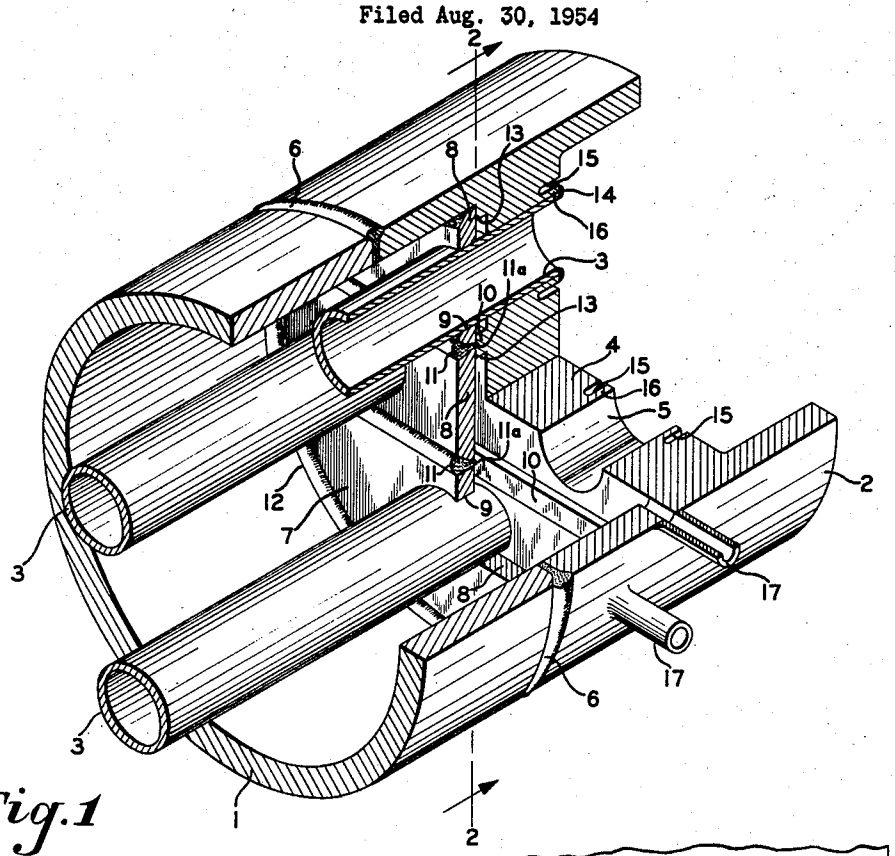


Fig. 1

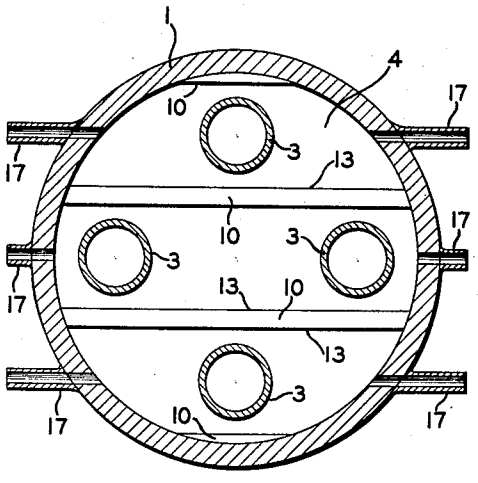


Fig. 2

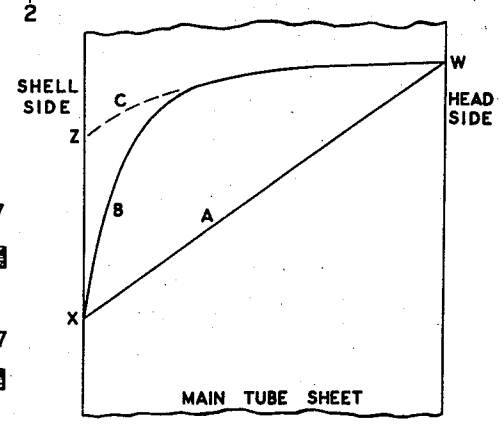


Fig. 3

INVENTOR.
Frank Boni, Jr.
BY
Frease & Bishop
ATTORNEYS

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HEAT EXCHANGER TUBE SHEET THERMAL SHIELD CONSTRUCTION

Frank Boni, Jr., Massillon, Ohio, assignor to The Griscom-Russell Company, Massillon, Ohio, a corporation of Delaware

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This invention relates to heat exchangers. More particularly, it pertains to improvements in a thermal shield for a tube sheet and in the detection of leakage at joints between the tube sheet and tubes attached thereto.

Inasmuch as a tube sheet separates the head side and the shell side of a heat exchanger, a temperature gradient occurs in the tube sheet due to the temperature differences of the fluids on each side. Where the temperature gradient is severe, thermal stresses are created in the tube sheet, having a detrimental effect.

If a flat plate is subjected to a high temperature on one side and to a low temperature on the other side, a linear temperature gradient would occur. If the edges of the plate are free, the plate will warp to a spherical surface in order to achieve a stress-free status. However, if the edges of the plate are not free, thermal stresses are set up as the result of retaining the plate in a plane.

With a tube sheet one entire face as well as interior portions of the plate are subjected to the temperature of the tube fluid, but only a portion of the other surface is subjected to the temperature of the shell fluid. The reason for this is that the tube sheet is provided with many openings in which are seated the ends of the heat exchanger tubes that extend through the shell. Thus, the tube fluid contacts the head surface of the tube sheet as well as the walls forming the openings in which the ends of the tubes are seated.

Moreover, the shell surface of the tube sheet is reduced because of the tubes extending from the openings. The result is that the tube sheet is subjected to a non-linear temperature gradient and thermal stresses are established regardless of whether or not the edge of the tube sheet is free. The severity of such thermal stresses is dependent upon the temperature difference between the fluids. This is particularly true on the shell side of the tube sheet which must absorb practically all of the tendency of the tube sheet to expand or contract.

Associated with the problem of expansion and contraction of the tube sheet caused by a temperature differential in the heat exchange fluids, is that of leakage detection. Due to the expansion and contraction of the tube sheet, the welded joints between the tubes and the tube sheet may become defective if the thermal stresses are extreme. In order to detect the fluid leakage due to such defects, it has been found expedient to monitor the joints at all times. For this purpose leakage grooves may be provided in the shell side of the tube sheet each of which grooves encompasses a small portion of the tube-to-tube-sheet joints. The grooves extend preferably parallel to each other across the tube sheet and are provided with separate outlets through the shell of the heat exchanger to the exterior.

The foregoing problems may be overcome by providing the shell side of the tube sheet with a secondary or outer tube sheet or thermal shield having a relatively small thickness compared with the thickness of the main tube sheet. The outer tube sheet is joined to the shell side of the main tube sheet in a fluid-tight manner and is provided with tube openings aligned with those of the main tube sheet. In this position the outer tube sheet closes the grooves in the main tube sheet, forming separate monitoring spaces around selected tube-to-tube-sheet joint.

Moreover, the outer tube sheet serves as a thermal barrier for the main tube sheet which minimizes the thermal stresses created in the main tube sheet due to the temperature difference between the heat exchange fluids. The resulting structure is one that enhances the detection and location of a leak as well as providing a thermal shock barrier for the main tube sheet.

Accordingly, it is a general object of this invention to provide a tube sheet construction for a heat exchanger having an outer tube sheet that insulates the main tube sheet from the temperature effects of the shell side fluid.

It is another object of this invention to provide a thermal barrier for the main tube sheet to minimize the effects of a differential temperature between the tube side and the shell side fluids.

It is also an object of this invention to provide a means for detecting tube joint leakage and to readily locate the same.

Another object of this invention is to provide a tube sheet construction having a relatively thin secondary tube sheet which provides closure for grooves disposed in the adjacent surface of the main tube sheet for the purpose of monitoring leakage through the tube sheet joints.

In addition, it is an object of this invention to provide a tube sheet construction having secondary tube sheet sections, each section extending over grooves disposed in the adjacent surface of the main tube sheet in order to facilitate repair of defective tube sheet joints.

Finally, it is an object of this invention to provide an improved tube sheet construction which substantially eliminates the defects enumerated and which obtains the foregoing desiderata in a simple and effective manner.

These and other objects apparent to those skilled in the art from the following description and claims, may be obtained, the stated results achieved, and the described difficulties overcome by the methods, steps, operations, procedures, arrangements, combinations and subcombinations which comprise the present invention, the nature of which is set forth in the following general statement, a preferred embodiment of which—illustrative of the best mode of which applicant has contemplated applying the principles—is set forth in the following description and shown in the drawings, and which are particularly and distinctly pointed out and set forth in the appended claims forming part hereof.

In general the nature of the improvements in tube sheet construction of the present invention may be stated as including a main tube sheet through which a plurality of heat exchange tubes extend and in which the ends of the tubes are welded or otherwise secured in a fluid-tight manner, the surface of the tube sheet adjacent the shell of the heat exchanger being provided with a number of shallow grooves aligned with the ends of the outer walls of each tube, the grooves being separated by lands integral with the tube sheet, said surface of the tube sheet being covered with secondary or outer tube sheet plates including sections covering each groove and extending between the lands, each section having a number of openings through which corresponding tubes extend, each heat exchange tube being expanded in an opening in a corresponding plate, and the plate sections being welded at their adjacent sides to each other and to corresponding lands and being welded at their periphery to the shell wall.

Referring to the accompanying drawing, which is illustrative of the preferred embodiment of the invention, by way of example, and in which similar numbers refer to similar parts thereof;

Fig. 1 is a somewhat diagrammatic, fragmentary view

of a portion of a heat exchanger as showing the improved tube sheet construction between the head member and the shell;

Fig. 2 is a vertical sectional view taken on the line 2—2 of Fig. 1; and

Fig. 3 is a graph showing temperature gradient curves through the main tube sheet.

The heat exchanger unit shown in Fig. 1 has a cylindrical shell 1 with a head member 2 at each end thereof. A number of heat exchange tubes 3 extend through the shell 1 and have end portions of each secured in a main tube sheet 4 which is provided with a number of tube-receiving openings 5 equal to the number of tubes 3. A tube sheet 4 separates the shell 1 from the head member 2 at each end thereof.

Although the heat exchanger is preferably cylindrical, and though the walls of the shell 1 and the head member 2 are shown integral with the tube sheet 4, these members may be fabricated separately and welded together by a weld similar to that indicated at 6, or the head member 2 and the tube sheet 4 may be formed integrally and secured by conventional means to the shell 1.

The tube sheet 4 is provided with a secondary or outer or shell side tube sheet, generally indicated at 7, on the side of the main tube sheet 4 adjacent the shell 1. The outer tube sheet 7 is composed of a number of plate sections 8 having a number of apertures 9 aligned with the tube-receiving openings 5 in the main tube sheet 4. Each plate section 8 extends over a portion of the tube sheet 4 and is secured to adjacent sections as well as to a corresponding land 10 by means of welds 11. In Fig. 1, each weld 11 extends through the thickness of the plate sections 8 and into the abutting surface at 11*a* of the corresponding land 10. In addition the ends of the sections 8 are welded at 12 to the interior surface of the shell 1.

As shown in Fig. 1, the surface of the main tube sheet 4 adjacent the outer tube sheet 7 is provided with a number of shallow groves 13 which are preferably of equal width and depth and have axes in alignment with rows of tube-receiving openings 5 (Fig. 2). Each groove 13 is preferably of width greater than the diameter of the openings 5 and thereby encompasses the joints between the openings and the corresponding tube 3 extending therethrough. Moreover, each groove 13 extends preferably horizontally across the surface of the main tube sheet 4 and is separated from adjacent grooves by the lands 10 which are integral with the main tube sheet.

The heat exchange tubes 3 have end portions secured within the main tube sheet openings 5 where they are welded in place at 14. In forming such welded joints, one practice has been to form a concentric trepan groove 15 around each tube opening 5, leaving an annular tube sheet portion 16 terminating flush with the head side surface of the tube sheet, within which annular portion the end of the tube is telescoped. Thereafter, the weld 14 is formed between the end of the tube 3 and the annular tube sheet portion 16.

Moreover, the tubes 3 extend through corresponding apertures 9 in the plate sections 8, where they are expanded in a fluid-tight manner in openings in the outer tube sheet 7, preferably by roller expanding.

With the sections of tube sheet 7 welded in place against the shell side of the main tube sheet 4, the edge portions of the sections 8 are integral with the lands 10. Each section 8 has a width equal to the distance between the center lines of adjacent lands 10. Thus, the grooves 13 are enclosed between parallel lands 10 and between facing surfaces of the main tube sheet 4 and the outer tube sheet 7.

Also, each groove 13 extends between the inner surfaces of the shell 1 (Fig. 2), whereby each groove serves as a sealed monitoring space or chamber that encompasses a row of joints between the tubes 3 and tube sheet 4. Hence, if a weld 14 becomes defective and results in leakage of a heat exchange fluid between the end portion of a tube 3 and the wall of the aperture 5, the leaking fluid may be detected in the monitoring space.

As shown in Figs. 1 and 2, communication between each groove 13 and the exterior of the heat exchanger may be had by means of separate ports 17 extending through the shell 1 from each groove 13. Similar ports 17 may be mounted at each end of the groove 13. Each row of tubes 3 is thereby separately monitored and the location of any leak is expedited, because a leak will be confined to a particular groove 13. If a heat exchange fluid leaks either from the head member 2 through the interface between a tube 3 and its opening 5, or from the shell side 1 through the interface between a tube 3 and its aperture 9, the presence of either fluid in a particular groove 13 is detected by a proper monitoring system circulating into and out of the particular groove through corresponding ports 17 to which proper inspection or detection means may be attached.

The tube sheet construction of the present invention is an improvement over previous constructions primarily because the secondary or outer tube sheet 7 serves as a thermal shield which is designed to decrease the temperature gradient through the main tube sheet 4. Thus, severe thermal stresses in the main tube sheet, which are occasioned by the exposure of opposite sides to heat exchange fluids of different temperatures, are minimized. As a thermal shield the outer tube sheet 7 is subject to some of the temperature differential, thereby reducing temperature differences causing severe thermal stresses in the main tube sheet. Such stresses, however, may cause the outer tube sheet 7 to yield or deform or even crack without severe harm to the heat exchanger or to its fundamental operation. Leakage of fluid from the shell 1 into the detection grooves 13 may result in filling the grooves 13 with an undesirable fluid from the standpoint of leakage detection, but such leakage would have no appreciable effect in increasing the thermal stresses in the main tube sheet 4.

The effect of the thermal stresses upon the main tube sheet 4 is graphically shown in Fig. 3. Curves "A," "B" and "C" show the temperature gradient across the thickness of the tube sheet 4 having a "Shell Side" and a "Head Side." Since the hotter fluid is ordinarily contained on the head side and in the tubes 3, all of the curves meet at a point "W" which is indicative of the temperature of said fluid. The cooler fluid in the shell 1 covers the "Shell Side" of the tube sheet 4. Its temperature is indicated at "X," somewhat lower than "W." The curve "A" represents the temperature gradient across the main tube sheet 4 if it were a solid plate, i.e., if it lacked tube-receiving openings 5. Under such a condition the opposite surfaces only of the tube sheet 4 would be exposed to the fluids.

Where the main tube sheet 4 is provided with tube-receiving openings 5, the hotter fluid has a greater influence upon the temperature gradient. In such case the hotter fluid is also located in the tubes 3 from which the heat is transmitted to the tube sheet 4 through the walls of the openings 5, causing the curve "B" to have a shape such as shown in Fig. 3. Curve "B" is substantially flat through about 80% of the main tube sheet 4, and then slopes downward sharply to terminate at "X." The foregoing description pertains to the main tube sheet 4 without a thermal shield or outer tube sheet 7.

Where the thermal shield or outer tube sheet is used, the temperature gradient across the main tube sheet 4 is shown by curve "C" which coincides with curve "B" over most of its length. A dashed portion of curve "C" near the "Shell Side" terminates at "Z" which is considerably higher than "X." In fact, the temperature "Z" is only slightly below the temperature "W." Accordingly, only a slight temperature gradient is present, resulting in less severe thermal stresses in the main tube sheet 4. With less thermal stresses, the tube sheet 4 is less

inclined to warp or deform or cause eventual breakdown in the joints between the tubes 3 and the tube sheet 4. Consequently, the thermal shield or outer tube sheet 7 is a definite advantage.

In addition, the detection and location of leaks is greatly improved because the monitored system is composed of several parts each of which is confined to a relatively small number of tubes 3. As is set forth above, each plate section 8 which encompasses a particular groove 13 is secured at its edges to an adjacent plate 8 as well as to a corresponding land 10 in a fluid-tight manner, as by the welds 11. In this manner the main tube sheet 4 serves to reinforce the relatively thin tube sheet 7 for which reason the latter is thinner than would be otherwise necessary, whereby expensive metal in the combined construction is considerably reduced. Finally, the foregoing construction is adapted to relatively easy fabrication, maintenance and repair of tubes for the reason that a single tube sheet section 8 covers only a particular tube or row of tubes.

In the foregoing description certain terms have been used for brevity, clearness and understanding, but no unnecessary limitations are to be implied therefrom beyond the requirements of the prior art, because such words are used for descriptive purposes herein and are intended to be broadly construed.

Moreover, the embodiment of the improved construction illustrated and described herein is by way of example, and the scope of the present invention is not limited to the exact details of construction shown.

Having now described the features, constructions and principles of invention, the characteristics of the new heat exchanger tube sheet construction, and the advantageous, new and useful results provided; the new and useful discoveries, principles, parts, elements, combinations, subcombinations, structures and arrangements, and mechanical equivalents obvious to those skilled in the art, are set forth in the appended claims.

I claim:

1. Heat exchanger tube sheet thermal shield construction including a head member, a shell member, a main tube sheet therebetween having a plurality of first tube-receiving openings formed therein, said tube sheet being provided with a plurality of grooves in the shell side thereof encompassing said openings, a thermal shield section overlying each groove within the shell member having a relatively small thickness compared with the thickness of the main tube sheet, each section being secured to the tube sheet and to an adjacent section, each section having a number of second openings formed therein aligned with corresponding first openings, a heat exchanger tube extending through each pair of aligned first and second openings, and each tube being secured to the main tube sheet and being expanded in the corresponding second opening in heat transfer contact.

2. Heat exchanger tube sheet thermal shield construction including a head member, a shell member, a main tube sheet therebetween having a plurality of first tube-receiving openings formed therein, said tube sheet being provided with a plurality of grooves in the shell side thereof encompassing said openings, an outer tube sheet within the shell member having a relatively small thickness compared with the thickness of the main tube sheet extending over the grooved surface of the main tube sheet, the outer tube sheet being composed of sections overlying each groove, each section being secured to the main tube sheet, at least some of the sections being secured to the shell, each section having at least one second opening formed therein aligned with a first tube-receiving opening, a heat exchanger tube extending through each pair of aligned first and second openings, and each tube being secured in each opening in a fluid-tight manner and in complete heat transfer contact therewith.

3. Heat exchanger tube sheet thermal shield construction including a head member, a shell member, a main tube sheet therebetween having a plurality of first tube-receiving openings formed therein, the tube sheet being provided with a plurality of spaced grooves in the shell side thereof encompassing said openings, the grooves being separated by lands integral with the main tube sheet, an outer tube sheet within the shell member having a relatively small thickness compared with the thickness of the main tube sheet extending over the grooved surface of the main tube sheet in a fluid-tight manner, the outer tube sheet being composed of sections overlying each groove, each section being welded to corresponding lands and to an adjacent section and having a number of second openings formed therein aligned with the first tube-receiving openings, a heat exchanger tube extending through each pair of aligned first and second openings, and each tube being secured in each opening in a fluid-tight manner and in complete heat transfer contact coextensive with the thickness of each tube sheet.

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