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HEAT EXCHANGER TUBE SHEET LEAKAGE PREVENTION
AND DETECTION CONSTRUCTION

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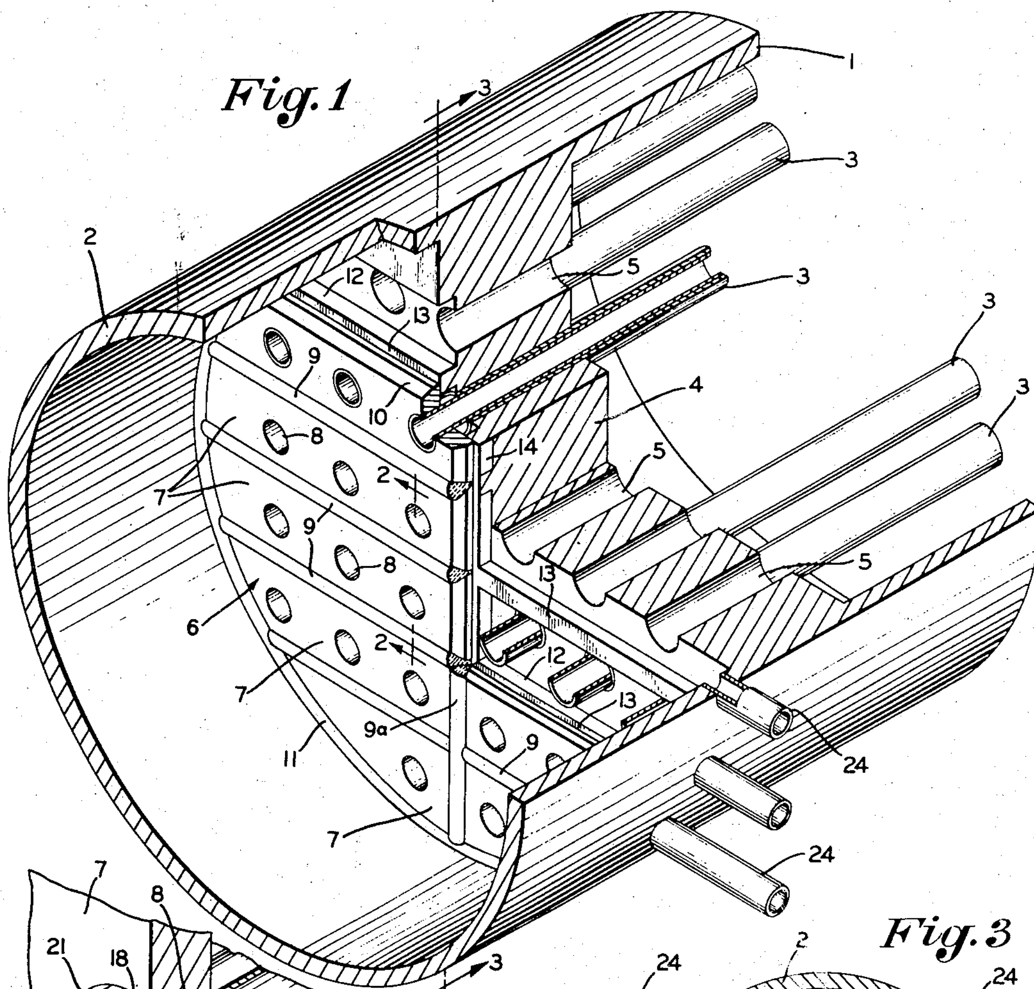
Fig. 1



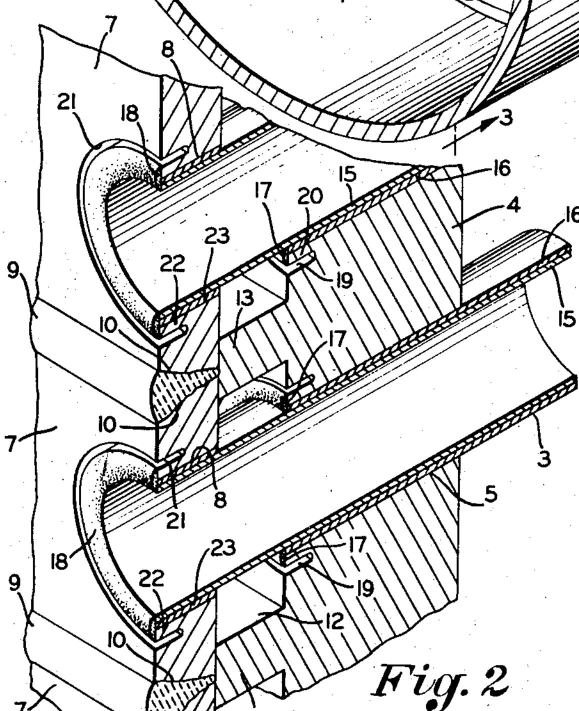
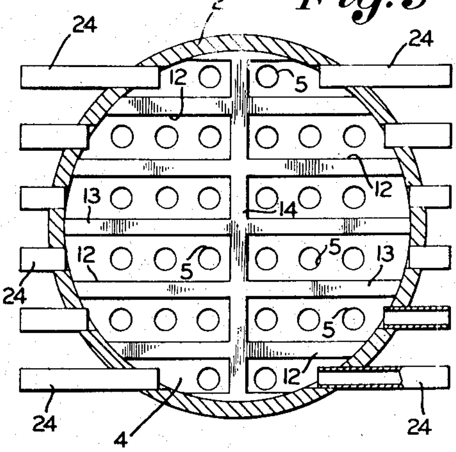


Fig. 2

Fig. 3



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1

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HEAT EXCHANGER TUBE SHEET LEAKAGE PREVENTION AND DETECTION CONSTRUCTION

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7 Claims. (Cl. 257—236)

This invention relates to heat exchangers. More particularly it pertains to improvements in tube and tube sheet construction for the detection and prevention of leakage of heat exchanger fluids; and the invention constitutes improvements upon certain constructions shown in the co-pending application of Bruegger and Otten Serial No. 380,214, filed September 15, 1953, and of Ris, Wallace and Otten Serial No. 417,344, filed March 19, 1954.

In the construction of tube sheets ordinarily used in heat exchangers of the type to be described herein, some difficulty is experienced with contamination of the fluids of the heat exchanger due to leakage at the joints between the tube sheets and tubes and subsequent leakage of one fluid into the other. With the development of heat exchangers having higher pressures and temperatures there is a necessity for effectively sealing the fluids against interleakage. Conventional tube and tube sheet construction does not satisfy the requirements of interleakage prevention.

Various means have been suggested to take care of this difficulty, including a double-tube construction in which each liquid-conducting tube is enclosed within an outer tube. A double tube construction prevents contamination of fluids when leaks develop in either tube or the tube sheet joints therewith, due to corrosion or any other reason. Thus, if one tube fails, the other serves as a barrier against fluid contamination until the defective tube can be replaced.

Associated with the problem of leakage prevention is that of leakage detection. Where double-walled tubes are used to prevent contamination of fluids, it is expedient to provide monitoring means in the tube sheet communicating with the interface between the tubes. Such means may include a chamber separated from both of the heat exchange fluids. However, where all of the tubes communicate with the same chamber, detection of the particular defective tube is difficult.

Moreover, the provision of a double-walled tube sheet enclosing a separate monitoring space or chamber increases the total amount of metal required for tube sheet purposes. This, in turn, not only adds to the expense of construction, but also creates problems of construction not inherent in single tube sheet heat exchangers.

We have discovered that these problems may be overcome by the provision of a single tube sheet having a number of shallow grooves in the head side thereof. An overlying plate, cover or inner tube sheet is mounted against the head side of the main tube sheet, providing grooves that encompass a few of the tube-to-tube sheet joints. The resulting structure is one that requires less metal for the same pressure requirements and that greatly improves the ability to detect and locate a leak as well as to assemble and repair it.

Accordingly, it is a general object of this invention to provide a tube sheet construction for a heat exchanger of double tube construction having leak detection spaces provided for a limited number of double tubes.

2

It is another object of this invention to provide a tube sheet construction having a greatly reduced amount of metal.

More particularly, it is an object of the invention to provide a double tube sheet construction for double tubes in a heat exchanger in which the double tube sheet requires only about 70% of the amount of metal required in prior double tube constructions involving spaced tube sheets.

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

It is another object of this invention to provide a tube sheet construction which facilitates the detection of leakage of fluids through the tube sheet joints.

It is another object of this invention to provide a tube sheet construction having thin secondary tube sheet plates, each covering only a portion of the main tube sheet surface, thereby facilitating replacement of defective tubes without the need of removing all of the plates.

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 and advantages 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, constructions, arrangements, combinations and sub-combinations which comprise the present invention, the nature of which are set forth in the following general statements, a preferred embodiment of which—illustrative of the best mode in which applicants have 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.

The nature of the improvements in tube sheet construction of the present invention may be stated in general terms 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 in a fluid-tight manner, each heat exchange tube being of double-walled construction, one surface of the tube sheet 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 inner tube sheet plates including small sections covering each groove and extending between and connected with the lands, each section having a number of openings through which corresponding tubes extend, and the inner wall of each heat exchange tube being welded to its corresponding plate in a fluid-tight manner, the plate sections being welded at adjacent sides to each other and to adjacent lands and the composite plate inner tube sheet being welded at its periphery to the heat exchanger wall.

By way of example, the improved tube sheet construction is shown in the accompanying drawings forming part hereof, wherein:

Fig. 1 is a somewhat diagrammatic, fragmentary, perspective of a portion of a heat exchanger showing the improved tube sheet construction between the head member and the shell;

Fig. 2 is an enlarged, fragmentary, perspective view, taken on the line 2—2 of Fig. 1; and

Fig. 3 is a vertical sectional view taken on the line 3—3 of Fig. 1.

Similar numerals refer to similar parts throughout the several views of the drawings.

The heat exchanger unit shown in Fig. 1 has a cylindrical shell **1** with a head member **2** at each end thereof. A bundle of heat exchange tubes **3** extend through the shell **1**. The opposite end portions of each tube **3** are secured in a main tube sheet **4**, provided with tube-receiving openings **5**. The tube sheet **4** separates the shell **1** from the head member **2** at each end thereof.

The heat exchanger is preferably cylindrical, and although 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, or the head member **2** and tube sheet **4** may be formed integrally and secured by any conventional means to the shell **1**.

As shown in Fig. 1 the tube sheet **4** is provided with a secondary or inner tube sheet, generally indicated at **6**, on the side of the main tube sheet **4** adjacent the head member **2**. The inner tube sheet **6** is composed of a number of similar sections **7** having a number of apertures **8** aligned with the tube-receiving openings **5** in the tube sheet **4**. Each section **7** covers a portion of the tube sheet **4** and is secured to adjacent sections as well as to a corresponding land **13** by means of welds **9**. In Fig. 2, the adjacent sides of the sections **7** are beveled at **10** to provide a V-shaped groove to facilitate the welding. Moreover, the ends of the sections **7** are welded at **11** to the inner surface of the head member **2**.

The surface of the tube sheet **4** adjacent the tube sheet **6** is provided with a number of shallow grooves **12** (Fig. 1). The grooves **12** are preferably of equal width and depth and have axes disposed in alignment with similar rows of tube-receiving openings **5** as shown in Fig. 3. Each groove **12** is preferably of a width greater than the diameter of the openings **5** and thereby encompasses the joints between the openings and the corresponding tubes **3** extending therethrough.

In addition, each groove **12** preferably extends across a half row of tube openings **5**. Adjacent grooves **12** are separated by lands **13** which are integral with the tube sheet **4**. The lands **13** preferably extend horizontally, and a vertical land **14** is provided, dividing a horizontal groove **12** into half portions. The adjacent ends of the sections **7** abut each other and overlie the vertical land **14**. The adjacent ends of sections **7** are welded together as well as to the vertical land **14**, as indicated by *9a* in Fig. 1.

Referring to Fig. 2 the heat exchange tubes **3** are shown having end portions secured within the tube sheet openings **5**. Each tube **3** is in fact a double tube unit having an inner tube **15** and an outer tube **16**. The end portion of the outer tube **16** is secured in the tube sheet **4** in a fluid-tight manner and preferably by a weld **17**. Likewise, the end portion of each inner tube **15** is secured within the apertures **8** in the tube sheet **6** in a fluid-tight manner and preferably by a weld **18**. In forming such welded joints one practice has been to form a concentric trepan groove **19** in the head face of the tube sheet **4** around each tube opening **5**, leaving an annular tube sheet portion **20** 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 **17** is formed between the end of the tube **16** and the annular tube sheet portion **20**.

In a like manner, a trepan groove **21** is formed in the head face of the tube sheet **6** around each aperture **8**, leaving an annular tube sheet portion **22** flush with the head side surface within which portion the end of the tube **15** is telescoped. Each aperture **8** has a diameter equal to that of each tube sheet opening **5** for the purpose of inserting or withdrawing outer tubes **16** if and when repair and replacement is necessary. Accordingly, each aperture **8** is provided with a ferrule **23** having a thickness substantially equal to that of the outer tube **15** whereby the end portion of the inner tube **15** fits snugly within the ferrule **23** in opening **8** where it is secured by the weld **18** to the ferrule **23** and to the annular tube sheet portion **22**.

With the sections **7** of the tube sheet **6** mounted in place against the head side of the tube sheet **4**, the abutting edges of the sections are disposed upon the edge of the lands **13**. That is, each section **7** has a width equal to the distance between center lines of adjacent lands **13**. Inasmuch as the grooves **12** are completely enclosed between parallel lands **13** and between facing surfaces of the tube sheet **4** and the tube sheet layer **6** and extend between the vertical land **14** at the center and the inner surface of the head member **2**, each groove serves as a sealed monitoring space which encompasses each half row of welded joints **17**. Communication between each groove **12** and the exterior of the heat exchanger may be had by means of separate ports **24** (Figs. 1 and 3) extending through the head member **2** from each groove **12**. By this construction each half layer of tubes is individually monitored and the location of any leak is expedited because a leak will be confined to a particular groove **12**. Hence, if a heat exchanger fluid leaks either from the shell **1** through the interface between the outer tube **16** and the opening **5**, or from the head side through the interfaces between the inner tube **15**, the ferrule **23** and the aperture **8** in the tube sheet layer **6**, the presence of either liquid in a particular groove **12** is detected by a proper monitoring system circulating into and out of the particular groove **12** through the corresponding port **24** to which proper inspection or detection means may be attached.

Moreover, the improved construction permits a considerable reduction in the amount of expensive material that may be required for the tube sheet construction for a double tube heat exchanger which protects against interleakage of heat exchanger fluids occasioned by any failure of either of the tubes of the double tube construction or of the joints between either of the tubes and their respective tube sheets.

In prior constructions, as in the Bruegger and Otten application Serial No. 380,214 where separate spaced tube sheets are utilized, each tube sheet will have a given thickness to take the required load.

Where two separate tube sheets such as the tube sheets **4** and **6** of the present construction, are used, in interface contact, sharing a common load through tubes tightly attached to both tube sheet members, the total thickness of the two tube sheets must be approximately 1.41 times the thickness of a single tube sheet taking the same load.

This is so because the tubes attached to both tube sheets in interface contact cannot maintain the two inner or contacting faces of the tube sheets at exactly the same diameter and they do not provide the necessary shear resistance between these faces that is provided by a layer of metallurgically bonded metal. In other words, the two tube sheets act much as the leaves of a spring, and it is, therefore, necessary to design the thickness of the main tube sheet **4** sufficiently strong enough to take the total load and to avoid shearing of the tube ends by the leaf spring action.

However, even though the total thickness of the two tube sheets **4** and **6** of the present invention is greater than that required of a single tube sheet taking the same load, and ignoring the thickness of the thin inner tube sheet of the improved construction, and by designing the main tube sheet for a total load, the tube sheet metal required per head is only 70% of that required for the construction, for instance, as shown in the Bruegger and Otten application Serial No. 380,214, because two thick tube sheets, spaced apart, are there required.

Finally, it is pointed out that even though a high pressure may be required in the monitoring grooves **12**, only a relatively thin secondary sheet for the inner tubes 15 is required because it is reinforced by the main tube sheet 4 at frequent intervals; i. e., at the lands 13 and 14 to which the sections 7 are welded.

The tube sheet construction of the present invention is an improvement over previous constructions for several reasons. In the first place the amount of expensive material required is considerably reduced. The sharing of the pressure loads by the tube sheet 4 and the tube sheet 6 which is peripherally welded to the head member 2 and to the lands, is made possible by the provision of the spaced lands by which relatively small areas of the head face surface of the tube sheet 4 are made integral with the facing surface of the tube sheet 6. In the second place the detection and location of leaks is greatly improved for the reason that the monitoring system is composed of a number of parts confined to a relatively small number of tubes. Finally, the foregoing construction is adapted to relatively easy fabrication, maintenance and repair of the tubes for the reason that a single tube sheet section 7 may have access to a particular tube or group of tubes without the necessity of removing the entire tube sheet 6.

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.

We claim:

1. Heat exchanger tube sheet leakage prevention and detection construction, including a head and a main tube sheet having a plurality of tube-receiving openings, the main tube sheet also having a plurality of shallow grooves in one surface each encompassing some of the openings, means communicating separately with each groove at the end thereof and the exterior of the head, an inner tube sheet extending over the grooved surface of the main tube sheet, the inner tube sheet being composed of sections extending over each groove, each section being secured to an adjacent section and to the main tube sheet and having a number of second openings corresponding to and aligned with the tube-receiving openings in the main tube sheet, a heat exchange tube member extending through each pair of aligned openings, each tube member including an inner tube secured in each second opening and an outer tube secured in each main tube sheet opening in a fluid-tight manner.

2. Heat exchanger tube sheet leakage prevention and detection construction, including a head portion, a shell portion, a main tube sheet between said portions and having a plurality of first tube-receiving openings, the main tube sheet also having a plurality of shallow grooves in the head side thereof, each groove encompassing some of said first openings, each groove extending to the outer edge of the main tube sheet, passage means communicating separately with each groove and extending through the head portion, an inner tube sheet abutting the surface of the main tube sheet including the grooves, the inner tube sheet being composed of sections covering each groove, each section being secured to an adjacent section and to the main tube sheet in a fluid-tight manner and having a number of second openings corresponding to

and aligned with the first openings in the main tube sheet, a heat exchange tube member extending through each pair of aligned openings, and each tube member including an inner tube secured in each second opening and an outer tube secured in each first opening in a fluid-tight manner.

3. Heat exchanger tube sheet leakage prevention and detection construction, including a head portion, a shell portion, a main tube sheet having a plurality of first tube-receiving openings, the main tube sheet also having a plurality of shallow grooves each encompassing some of said first openings, the grooves being separated by lands integral with the main tube sheet, passage means communicating separately with each groove and extending through the head portion, an inner tube sheet overlying the entire surface of the main tube sheet, the inner tube sheet being composed of sections extending over each groove, each section being welded to an adjacent section and to corresponding lands, the edge of the inner tube sheet being welded to the head portion, each section having a number of second openings corresponding to and aligned with the first openings in the main tube sheet, a heat exchange tube member extending through each pair of aligned openings, and each tube member including an inner tube secured in each second opening and an outer tube secured in each first opening in a fluid-tight manner.

4. Heat exchanger tube sheet leakage prevention and detection construction, including a head portion, a shell portion, a main tube sheet therebetween and having a plurality of first tube-receiving openings, the openings being aligned in parallel rows, the main tube sheet also having a plurality of shallow grooves in the head side thereof, each groove encompassing several of the aligned openings and extending to the outer edge of the main tube sheet, passage means communicating separately with each groove and extending through the head portion, an inner tube sheet abutting the head surface of the main tube sheet, the inner tube sheet being composed of sections extending over each groove, each section being welded to an adjacent section, to the main tube sheet, and to the head portion, each section having a number of second openings aligned with the first openings in the main tube sheet, a heat exchange tube member extending through each pair of aligned openings, and each tube member including an inner tube secured in each second opening and an outer tube secured in each first opening in a fluid-tight manner.

5. Heat exchanger tube sheet leakage prevention and detection construction as set forth in claim 4 in which the inner tube extends through one of said grooves between the second opening, in which it is secured, and the first opening, in which its corresponding outer tube is secured.

6. Heat exchanger tube sheet leakage prevention and detection construction as set forth in claim 4 in which the end portions of the tubes are welded in their respective openings.

7. Heat exchanger tube sheet leakage prevention and detection construction, including a head portion, a shell portion, a main tube sheet therebetween and having a plurality of first tube-receiving openings, the openings being aligned in parallel rows, the main tube sheet also having a plurality of shallow grooves in the head side thereof, each groove encompassing half of each row of openings, each groove being separated from an adjacent groove by parallel lands protruding from the surface of the main tube sheet and integral therewith, each groove extending to the outer edge of the main tube sheet, the grooves encompassing half rows of openings in a particular row being separated from each other by a land protruding from the surface of the main tube sheet and perpendicular to said parallel lands and integral therewith, passage means communicating separately with each

groove and extending through the head portion, an inner tube sheet abutting the grooved surface of the main tube sheet and being composed of sections extending over corresponding grooves between the center lines of adjacent parallel lands, each section being welded to an adjacent section and to corresponding lands and having a number of second openings aligned with the first openings in the main tube sheet, a heat exchange tube member extending through each pair of aligned openings, the tube member being composed of an inner tube and an outer tube, the outer tube being seated within one of said first openings in the main tube sheet, to which its extremity is

welded, and the inner tube extending through a corresponding groove and into one of said aligned second openings in the inner tube sheet, to which it is welded.

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