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HEAT EXCHANGER TUBE SHEET JOINT CONSTRUCTION

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The invention relates to heat exchangers, and more particularly to a new arrangement of the tubes, tube sheet and the manner in which the tubes and tube sheet are joined.

Recent designs of heat exchangers have involved certain requirements that are difficult to collectively satisfy. A compact tube bundle arrangement with a close spacing between tubes in some cases as small as five-fourths of the tube outside diameter is desired for a number of reasons. First of all, high velocity of shell fluid flowing across the tube surfaces may be desired. The closer the tube spacing, the higher are the velocities that may be obtained. Second, a compact tube bundle arrangement reduces the size and weight of the equipment, which are extremely important considerations in some types of heat exchanger installations.

Next, the fluids, temperatures or pressures involved may dictate that welded joints between tubes and tube sheets must be provided. Heretofore it has been impractical to provide welded joints between tubes and tube sheets with a compact tube bundle arrangement excepting by extending the tube ends through the tube sheet and welding the tube ends and tube sheet together on the head side of the tube sheet, for instance, as illustrated in the Gardner application Serial No. 437,080, filed June 16, 1954, Patent No. 2,807,445, granted September 24, 1957.

However, where the tube ends extend through the tube sheet and are welded to the tube sheet at the head side thereof, there is a crevice between the tube and the holes in the tube sheet on the shell side of the tube sheet in which a concentration of solids emanating from the shell fluid may accumulate. Such deposit of solids at such crevices may cause serious difficulties through galvanic action or for other reasons where certain shell fluids are involved. Accordingly, there has been a further requirement that such crevices must be eliminated in certain heat exchanger designs. This, in turn, requires that the joint between the tubes and tube sheet must in some manner be located on the shell side of the tube sheet.

However, where such joints are required to be welded joints, it has heretofore been impossible to satisfactorily form the same and at the same time maintain a close tube spacing because of the necessity of providing room for access to the tubes and the adjacent surface of the shell side of the tube sheet for forming the required welded joints.

Furthermore, in addition to the close tube spacing, welded joint and crevice elimination requirements, there may be a further requirement for inspection, such as X-ray inspection for soundness, of the welded joints after they are formed. Welded joints at the head side of a tube sheet may be formed in certain designs which are accessible for inspection but accessibility of welded joints for inspection if located at the shell side surface of the tube sheet is difficult.

Heretofore, there has been no known tube and tube

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sheet construction for heat exchangers which could be fabricated to collectively satisfy the stated requirements.

We have discovered a new joined tube and tube sheet construction and arrangement which satisfies the existing need and the indicated requirements and which includes closely spaced or nested tubes providing a compact tube arrangement, integral extensions, thimbles or nipples on the shell side of the tube sheet, and internally welded, butted joints between the ends of the extensions and the ends of the tubes.

Accordingly, it is a general object of the present invention to provide a new heat exchanger tube and tube sheet arrangement collectively satisfying the stated requirements which have created an existing need in the art.

Furthermore, it is an object of the present invention to provide a new tube and tube sheet construction and arrangement for heat exchangers which enables a compact arrangement of closely spaced tubes to be provided with welded joints between the tubes and tube sheet adjacent and spaced from the shell side surface of the tube sheet, capable of inspection after completing the welded joints and eliminating crevices at the junctions of the tube connections with the tube sheet.

Finally, it is an object of the present invention to provide a new tube and tube sheet construction and arrangement for heat exchangers which overcomes the difficulties heretofore encountered in the art, which satisfies an existing need, which obtains many new results and advantages herein set forth, and which may be readily fabricated in a simple and inexpensive 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 discoveries, parts, combinations, subcombinations, constructions, arrangements and elements, which comprise the present invention, the nature of which is set forth in the following general statement, preferred embodiments of which—illustrative of the best modes in which applicants have contemplated applying the principles—are set forth in the following description, and which are distinctly and particularly pointed out and set forth in the appended claims forming part hereof.

The nature of the improvements in tube and tube sheet construction of the present invention may be stated in general terms as preferably including shell walls forming a shell chamber, head walls forming a head chamber, a tube sheet separating the shell and head chambers, a series of tube openings formed in the tube sheet, a series of tubes, the spacing between the tube openings in the tube sheet being adapted to be located as close as up to five-fourths of the outside diameter of the tubes, tubular extensions connected integrally with the shell side of the tube sheet at the shell end of each tube opening formed in the tube sheet, the ends of said tubular extensions being spaced from the shell side surface area of the tube sheet immediately surrounding the extensions, the ends of the tubes abutting the spaced ends of said extensions, an internal welded joint between said butted ends of the tubes and tube sheet tube opening extensions, and said spacing between the ends of the extensions and the surrounding tube sheet shell side surface providing interior and exterior accessibility to the internally welded end-butted joints.

By way of example, preferred embodiments of the improved construction and arrangement are illustrated in the accompanying drawing forming part hereof wherein:

Figure 1 is a fragmentary sectional view of a heat exchanger constructed in accordance with the invention; Fig. 2 is an enlarged fragmentary sectional view illus-

trating one form of improved tube and tube sheet arrangement;

Fig. 3 is a view similar to Fig. 2 showing a modified form of construction;

Fig. 4 is a view similar to Figs. 2 and 3 illustrating another modified form of construction; and

Fig. 5 is a fragmentary view looking in the direction of the arrows 5—5, Fig. 1.

Similar numerals refer to similar parts throughout the various figures of the drawing.

A typical heat exchanger is illustrated generally in Fig. 1 including a shell 1, head barrel walls 2 forming a head chamber 3, a tube fluid inlet 4, a tube fluid outlet 5, a tube sheet 6 separating the shell 1 and head chamber 3, and pass separation partitions 7.

The tube sheet 6 is provided with the desired number of tube openings 8, which are spaced as closely together as possible, minimum normal tube spacing being five-fourths of the outside diameter of the tubes. The tube spacing is represented by the line S in Fig. 5.

As shown in Figs. 1 and 2, an integral tubular neck, projection, thimble or extension 9 is formed on the shell side 10 of the tube sheet 6 forming the inner or shell end of each opening 8; and each projection 9 has its inner end 11 spaced inwardly of the shell side tube surface area 12 immediately surrounding the extension 9. Preferably the extension 9 is formed at its integral connection with the tube sheet 6 with a rounded fillet 13.

Heat exchange tubes 14 are located within the shell 1 connected with extensions 9 and provide for tube fluid flow from the head chamber 3 through the tubes 14 into chamber 15 within the pass separation partition 7 and out through outlet 5.

The ends 16 of the tubes 14 are butted against the ends 11 of tube sheet extensions 9 and are welded thereto by internal circumferential welds 17 providing welded connections between the tubes 14 and the tube sheet 6.

The internal welds 17 may be formed with a rotatable arc welding tool such as disclosed in the copending application of Raymond Gardner, Jr., filed March 28, 1957, Serial No. 649,186, now Patent No. 2,868,953, granted Jan. 13, 1959.

The particular construction and arrangement of the tube and tube sheet with the ends of the tubes butted against extensions on the shell side surface of the tube sheet and internally welded thereto enable a very close spacing of tubes to be provided in the heat exchanger design, thus resulting in a compact tube bundle arrangement which permits high velocity flow of shell fluid across the tube surfaces within the shell 1 and reduces the size and weight of the heat exchanger and its component parts to a minimum.

The improved construction further eliminates any crevices which heretofore have been present when heat exchanger tubes extend through tube openings in a tube sheet to the head side surface thereof. Such crevices are present at the corners between the outer surfaces of the tubes and the shell side surface of the tube sheet. The improved construction in eliminating these crevices enables the filleted contour 13 to be used which is desirable from the standpoint of stress resistance at the tube connection juncture with the tube sheet. Further, since the ends of the extensions 9 are spaced from the tube sheet shell side surface area immediately surrounding the connection juncture of the extensions 9 with the tube sheet 6, and since the welds 17 are likewise similarly spaced, being located between the butted ends 16 and 11, respectively of the tubes 14 and extensions 9, the welds 17 are spaced from the place of maximum bending due to discontinuity stresses, that is at the juncture of the tubular extensions 9 with the tube sheet 6.

Furthermore, the location of the welds 17 spaced from the surrounding shell side tube sheet surface area 12 permits access for inspection to the welds 17 after the welding operations have been completed. Thus, such

inspection may be carried out by slipping a ring or spool of film onto the tube 14 around weld 17 and exposing the same to a gamma ray source located inside the tube. It is impossible to perform such a weld inspection operation if the welded joint is located at the juncture of the tube with the tube sheet.

The extensions 9 may be formed integrally with the tube sheet 6 by forging procedures if desired, or a thicker tube sheet member than illustrated in Figs. 1 and 2 may be machined to form the necessary cross-sectional configuration to provide integral tube connection extensions 9.

The close tube spacing is achieved in the new construction by forming the welds 17 as internal welds between the abutted ends 16 and 11 of the tubes 14 and extensions 9. Referring to Fig. 5, it would be impossible to provide the close tube spacing S these illustrated with an exteriorally formed welded joint because of the inability to gain the circumferential access necessary to form the weld exteriorly of the tube.

Although the heat exchanger construction illustrated somewhat diagrammatically and generally in Fig. 1 can be a typical feed water heater construction, the use of the improved construction is not limited to feed water heaters. The improved arrangement may be used wherever heat exchange tubes of any type are connected with a tube sheet of any type, in any type of heat exchanger in a closely spaced relation with an internally welded joint located at a position spaced from the immediately surrounding area of the shell side tube sheet surface.

Although the internal welds 17 may be formed in accordance with resistance or flash welding procedures if welding equipment for performing such operations and the dimension of the parts, permits; it is preferred that the welds 17 be formed as arc welds using a shielded arc tungsten tip welding tool and without the use of a consumable welding rod.

The location of the welds 17 spaced from the connection of the extensions 9 with the tube sheet in addition to providing accessibility for weld inspection also locates the welds away from the connection of the extensions 9 with the tube sheet body so as to minimize the effect of heating, in carrying out the welding operations, upon the metal at the juncture between the extensions 9 and the body of the tube sheet.

In the modified form of construction shown in Fig. 3, the extensions 9a may be formed in the tube sheet 6a by machining annular grooves 18 in the shell side surface of the tube sheet 6a around each tube opening 8. In this manner a fillet 13a is formed at the juncture between the extension 9a and the body of the tube sheet metal 6a. Accordingly, the ends of the extensions 9a are spaced from the area of the shell side tube sheet surface immediately surrounding the base of the extensions 9a at the juncture of said extensions with the body of the tube sheet at the base of the grooves 18. Thus, the grooves 18 permit the use of a film ring surrounding the weld 17a for weld inspection since the welded joint is accessible exteriorly and interiorly for such inspection.

Obviously, the shape or contour of the shell side surface of the tube sheet 6a in Fig. 3 is but a stage in forming the shape of the shell side of the tube sheet 6 in Fig. 2 where the tube sheet contour is formed by machining operations. Thus, if the tube sheet 6a illustrated in Fig. 3 is machined further to cut away the metal 19 surrounding the groove 18, the shell side contour of the tube sheet 6a becomes that of the tube sheet 6.

As a further alternative, the extensions against which the tube ends are abutted (Fig. 4) and welded internally may be formed as indicated in Fig. 4 at 20 by a procedure such as disclosed in the Gardner Patent No. 2,807,445.

Accordingly, the present invention provides a new tube and tube sheet construction and arrangement for

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heat exchangers which enables a compact arrangement of closely spaced tubes to be provided with welded joints between the tubes and tube sheet adjacent and spaced from the immediately surrounding shell side surface of the tube sheet, capable of inspection after completing the welded joint and eliminating any crevice at the juncture of the tube connection with the tube sheet; and provides a construction satisfying the existing need and obtaining the new results indicated in a simple and effective manner.

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 terms are utilized for descriptive purposes herein and not for the purpose of limitation and are intended to be broadly construed.

Moreover, the description of the improvements is by way of example, and the scope of the present invention is not limited to the exact details illustrated and described.

Having now described the various features, discoveries and principles of the invention, the construction and arrangement of preferred forms of improved tube and tube sheet connections, and the advantageous, new and useful results obtained thereby; the new and useful discoveries, principles, parts, combinations, sub-combinations, construction, arrangements and elements, and mechanical equivalents apparent to those skilled in the art, are set forth in the appended claims.

We claim:

1. In a heat exchanger of the type wherein a tube

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sheet having a shell side surface and a head side surface is provided with a series of tube openings; a series of heat exchange tubes closely spaced together on the shell side of the tube sheet, tubular extensions integral with and extending free of crevices from the tube sheet on the shell side thereof forming the shell ends of the tube sheet openings, the ends of said tubular extensions being spaced from the shell side surface area of the tube sheet immediately surrounding the juncture of the extensions with the tube sheet, the ends of the tubes abutting the ends of corresponding tubular extensions, an internally applied heat welded joint between said abutted ends of the tubes and the extensions, said welded joint being a fusion weld of said abutting ends free of added filler metal directly between said abutted ends, and the spacing between the ends of the extensions and the surrounding tube sheet shell side surface area at the juncture of the extensions with the tube sheet providing internal and external accessibility to the internally fusion welded end-abutted closely spaced joints.

2. The construction defined in claim 1 in which the spacing between the centers of the tube openings is as close as up to five-fourths of the outside diameter of the tubes.

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