This invention relates to heat exchangers and more particularly to heat exchangers of the type comprising a shell containing metal tubes the ends of which are mounted in tube sheets located near the ends of the shell.

One of the objects of this invention is to provide a heat exchanger in which the heat exchanger tubes are so disposed within the shell that it is unnecessary to provide baffles, or other means, to secure the desired velocity of the fluid passing through the shell along the exterior surfaces of the tubes.

The ordinary shell and tube heat exchanger is provided with a plurality of tubes which are necessarily spaced a considerable distance from each other in order to secure the necessary support for the tubes in the tube sheets. The tubes are not placed close together in the ordinary exchanger because this would greatly weaken the tube sheets; there would not be sufficient bridge wall between the ends of adjacent tubes to provide the necessary strength. The tube sheets must be capable of withstanding considerable stress caused by the expansion and contraction of the tubes and accordingly the holes in the tube sheets must be spaced far enough apart so that the tube sheets will possess the requisite strength.

The apparent necessity for spacing the tubes a considerable distance apart in order to avoid the use of structurally weak tube sheets has led to the practice of employing baffles within the shell to produce sufficient velocity outside of the tubes for effective heat transfer. Most baffle arrangements produce eddy currents and high pressure drops but they have nevertheless been used to a very large extent because of the fact that the cross sectional area of flow outside the tubes of an ordinary exchanger is considerably in excess of the cross sectional area of flow inside the tubes.

The use of baffles is objectionable for a number of reasons. For example, a heat exchanger containing baffles must be cleaned at frequent intervals and it is difficult to clean such an exchanger, especially where a close baffle pitch is employed, and this is true regardless of whether the tube bundle is removable. Furthermore, it is necessary to machine the inner surface of the shell so that the baffles will be in contact with the shell at all points and prevent by-passing of the fluid between the baffles and the shell.

The present invention involves the use of tubes so constructed and arranged within the shell that the use of baffles can be eliminated. The shell may be substantially filled with tubes spaced close enough to each other to insure sufficient velocity outside of the tubes for effective heat transfer and this is accomplished without using structurally weak tube sheets. The holes in the tube sheets for receiving the ends of the tubes may be spaced far enough apart to provide sufficient bridge wall in the tube sheets, even though the tubes are spaced close together. In general, this is accomplished by swedging one or both ends of each of the tubes so that the swedged end or ends of each tube are of smaller diameter than the remaining portion of the tube. Where only one end of each tube is swedged the alternate tubes are reversed. Our improved construction and arrangement of the tubes is such that the tube bundle substantially fills the shell even where the tube sheets are of smaller diameter than the inside diameter of the shell. The compact arrangement of the tubes makes it possible to use a shell of smaller diameter than is ordinarily employed and the absence of baffles removes the principal cause of fouling. Furthermore, our improved heat exchanger is much easier to clean than the ordinary exchanger regardless of whether the tube bundle is removable. The cross sectional area of flow through the shell need not be greater than the cross sectional area through the tubes and it may be even smaller than the cross sectional area through the tubes. The arrangement of the tubes is such that relatively small flow passages are provided between the tubes, and the swedged ends of the tubes may be of sufficient length to provide adequate space at the ends of the tube bundle to insure adequate distribution of the fluid entering the shell.

The various objects and advantages of my invention will be more apparent upon considering the following detailed description of certain embodiments of the invention illustrated in the accompanying drawings in which:

Fig. 1 is a longitudinal section view of a heat exchanger having a floating head and a removable tube bundle;

Fig. 2 is a longitudinal section view of a heat exchanger having a floating head and a non-removable tube bundle;

Fig. 3 is a longitudinal section view of a heat exchanger in which the tube sheets are permanently secured to the shell;

Fig. 4 is a transverse sectional view taken on line 4—4 of Fig. 1 showing details of construction;

Fig. 5 is a transverse section view taken on line 5—5 of Fig. 1 showing a tube support for maintaining the tubes in proper position within the shell;
Fig. 6 is a side elevation partly in section of the tube support forming a part of the apparatus shown in Figs. 1 and 5. Fig. 7 is an enlarged elevation of a portion of one of the tubes shown in Figs. 1 to 5 inclusive; Fig. 8 is a longitudinal section view of another form of exchanger in which the tube sheets are permanently secured to the shell; and Fig. 9 is a transverse section view taken on line 9-9 of Fig. 8 showing details of construction.

The heat exchanger of Fig. 1 comprises a shell 1 mounted on suitable supports 2 and 3 and provided with an inlet 4 near one end and an outlet 5 near the other end. The shell 1 encloses a tube bundle which may be regarded as comprising two sets of tubes 6 and 7. The tubes 6 have swedged ends 6' mounted in a tube sheet 8 in any suitable manner such as by expanding the ends of the tubes into the tube sheet. The tubes 7 have swedged ends 7' expanded or otherwise mounted in a tube sheet 9. The large ends of the tubes 6 are also mounted in the tube sheet 9 and the large ends of the tubes 7 are mounted in the tube sheet 8. The tubes 6 and 7 may be identical except for their arrangement within the shell and it will be noted that alternate tubes are reversed so that the swedged ends of the tubes 7 are at one end of the shell and the swedged ends of the tubes 6 are at the opposite end of the shell.

The heat exchanger of Fig. 1 is of the type having a floating head and a removable tube bundle. Accordingly, the tube sheet 8 is of larger diameter than the internal diameter of the shell and the edge of the tube sheet is secured to a flange 10 on the shell by any suitable means such as the bolts 11. The exchanger is of the double pass type and the stationary head 12 is provided with an inlet 13 at the bottom thereof and an outlet 14 at the top thereof, the inlet 13 being in communication with a manifold chamber 15 and the outlet being in communication with the manifold chamber 16. The manifold chambers 15 and 16 are separated by a baffle 17 and the outer wall of each chamber is formed by a removable cover plate 18 held in place by the bolts 11. The floating head 19 at the opposite end of the shell comprises a return bonnet 20 and a split ring 21. The bonnet 20 and the ring 21 engage opposite sides of the edge of the tube sheet 9 and are clamped together by bolts 22, suitable spacers 23 being disposed between the rim of the bonnet 20 and the split ring 21. A cover 24 closes the end of the shell and it will be understood that by removing the cover 24 and the bonnet 20, the spacers 23 and the split ring 21 may be removed, and then, when the stationary head 12 at the other end of the shell is removed, the tube bundle may be withdrawn from the shell. The tube sheet 9 is of smaller diameter than the internal diameter of the shell to permit the removal of the tube bundle from the shell.

A tube support 25 may be employed if desired and this tube support is preferably of the form illustrated in Figs. 3, 5, and 6. The support consists of two sections of metal nested together to form a group of rectangular apertures through which the tubes pass. Each section of the tube support comprises a plurality of strips of sheet metal each provided with slits extending approximately halfway across the strip so that the two sections can be nested together with the strips of one section extending at right angles to the strips of the other section. The strips of one section are shown at 26 and those of the other section at 27. It will be understood that the tubes are passed through the tube support before the ends of the tubes are expanded or otherwise fixed to the tube sheets. The tube support may be fixed to the shell, or merely loosely mounted therein, depending upon whether the tube bundle is to be removable. Where the tube support is to be secured to the shell it is feasible to drill holes through the shell and then fill these holes with molten metal which makes contact with the tube support and anchors that portion of the shell sheet to the shell. It will be noted that the swedged ends 6' of the tubes extend a considerable distance into the shell from the tube sheet and preferably to a point beyond the inlet 4. This is to provide ample space at the end of the shell for insuring adequate distribution of the fluid entering the shell so that the fluid will flow through all of the spaces between the tubes to the opposite end of the shell. In like manner the swedged ends 7' of the tubes extend into the shell a considerable distance from the tube sheet 9, the tube sheets 8 and 9 providing ample space for the fluid to pass upward to the outlet 5. The shell outlet 5 is preferably located at the top of the shell to avoid gas binding.

By using tubes each of which is swedged at one end as illustrated in Fig. 1, it is possible to have the holes in the tube sheets far enough apart to provide ample bridge walls between adjacent holes. Inasmuch as each tube is swedged at one end only it is possible to remove a defective or damaged tube without much difficulty. For example, the tubes 6 can be withdrawn through the tube sheet 8.

The heat exchanger in Fig. 2 is similar to that shown in Fig. 1 except that the tube bundle is not removable. The tube sheet 28 is welded, or otherwise fixed to the shell 29. The cover 24 at the opposite end of the shell 29 encloses a tube sheet 115, 116, 117, 118, 119 to which is attached the return bonnet 31 by means of bolts 32. The tube sheet 30 and the bonnet 31 constitute a floating head loosely mounted within the cover 24. The tubes 6 and 7 in the apparatus of Fig. 1 and other corresponding parts have been marked with the same reference numerals employed in Fig. 1.

In Fig. 3 the shell 33 encloses a tube bundle comprising 6 tubes 6 similar to the tubes 6 shown in Figs. 1 and 2. The tube sheets 34 and 35 of the apparatus in Fig. 3 are both welded or otherwise fixed to the shell 33 and, accordingly, this apparatus does not have a floating head. The ends 13 of the shell are closed by cover plates 36 and 37. The apparatus of Fig. 3 is of the single pass type and, accordingly, the tube inlet 38 is located at one end of the shell and the tube outlet 44 at the opposite end. The apparatus of Figs. 1, 2 and 3 includes tubes each having one end thereof swedged and the alternate tubes are reversed.

In Fig. 8 the shell 39 is of tubular form having screw threaded covers 40 and 41 at the ends thereof. This apparatus is similar to that of Fig. 1 in that the single pass type with a tube inlet 42 at one end of the shell and a tube outlet 43 at the opposite end. The shell inlet is shown at 44 and the shell outlet at 45. The tube sheets 46 and 47 are both cathodically, or otherwise 1-electrolytically, galvanically, or by other means secured to the shell 39. Each of the tubes 48 within the shell 39 has each end thereof of reduced cross section. By swedging both ends of each tube it is possible to mount the tubes even closer together than is the case
with the form of construction shown in Figs. 1, 2 and 3. Fig. 9 represents a suitable arrangement of the tubes within the shell and it will be noted that the rows of tubes may be spaced apart a distance less than the diameter of the tubes. The vertical rows of tubes are vertically displaced and nested together so that the tubes nearly touch each other. In fact for some installations it may be appropriate to have the tubes in contact with each other and this can be accomplished without having the swedged ends of the tubes so close together that the tube sheets are unduly weakened. In Fig. 9 the tubes are arranged with the tube centers in triangular relation, that is, lines drawn through all of the tube centers would form a series of triangles because of the staggered relation of the rows of tubes. The construction shown in Fig. 8 is very inexpensive because the apparatus in this form does not have a floating head and no provision is made for removing the tube bundle. The form of apparatus shown in Fig. 3 is also quite inexpensive and for the same reason. The apparatus shown in Fig. 2 is somewhat more expensive because of the floating head construction but is less expensive to manufacture than the form shown in Fig. 1 in which the tube bundle is removable. The various modifications illustrated in Figs. 1 to 9 inclusive illustrate the commercial utility of the invention for it is possible to use the invention to advantage in various types of heat exchanger apparatus. In all cases it is possible to mount the tubes close together with the tube bundles substantially filling the shell, thus making it unnecessary to use baffles. By swedging down one or both ends of each tube the maximum number of tubes can be accommodated within a shell of given diameter and at the same time sufficient bridge wall is permitted in the tube sheets to provide the necessary strength. By making the swedged down portion of each tube relatively long, ample entrance and exit areas are provided opposite the inlet and outlet ports for the liquid passing through the shell.

It is to be understood that my invention is not limited to the particular embodiments illustrated and described but includes such modifications thereof as fall within the scope of the appended claim.

I claim:

A heat exchanger comprising a shell, tube sheets disposed at the ends of the shell, a lateral fluid inlet near one end of the shell, a lateral fluid outlet near the other end of the shell, a tube bundle substantially filling said shell and secured to said tube sheets, each tube of said bundle having one end portion thereof of reduced cross section and alternate tubes being secured to said tube sheets in reversed relation, whereby ample bridge wall is provided in each tube sheet between adjacent tubes, the said end portions being of sufficient length to provide transverse flow paths communicating with said inlet and outlet respectively.

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