

May 5, 1964

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3,131,758

HEAT EXCHANGER APPARATUS

Filed June 4, 1959

3 Sheets-Sheet 1

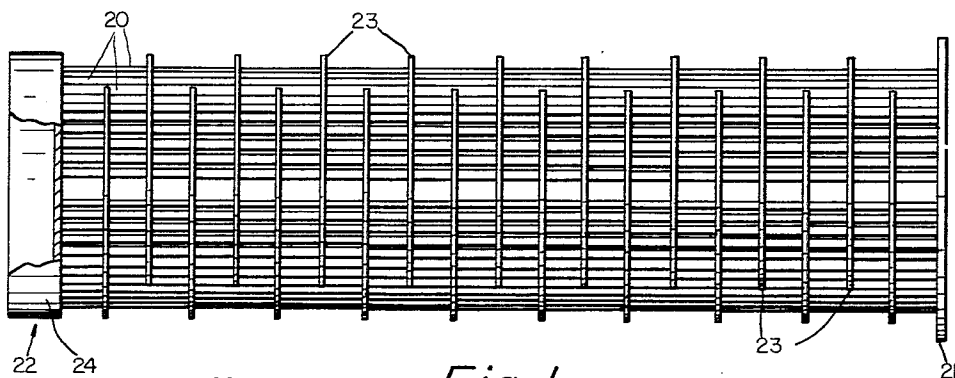


Fig. 1

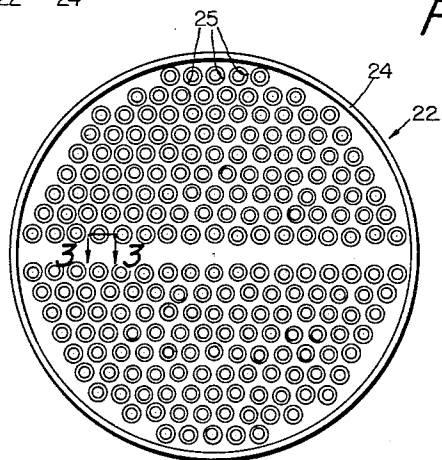


Fig. 2

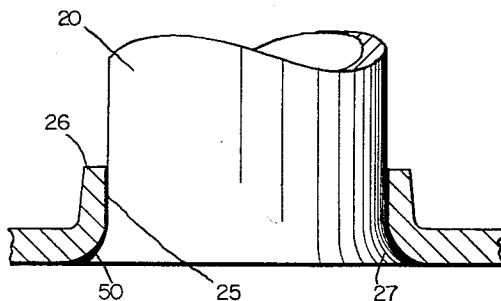


Fig. 3

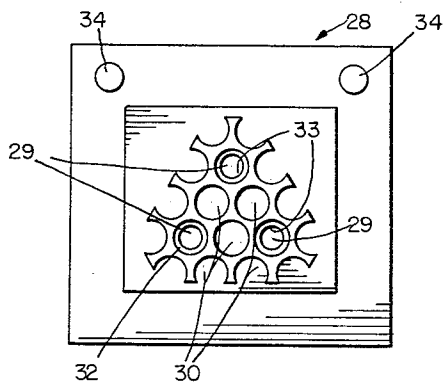


Fig. 4

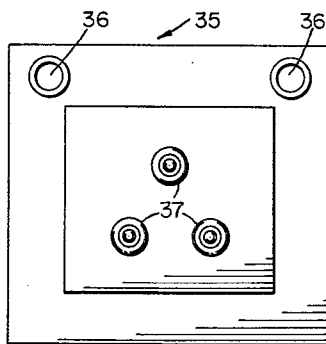


Fig. 4a

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3 Sheets-Sheet 2

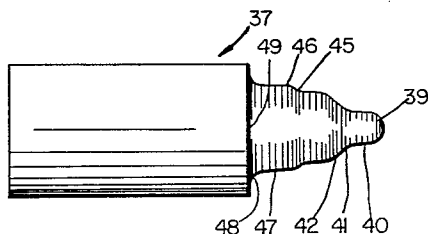


Fig. 5

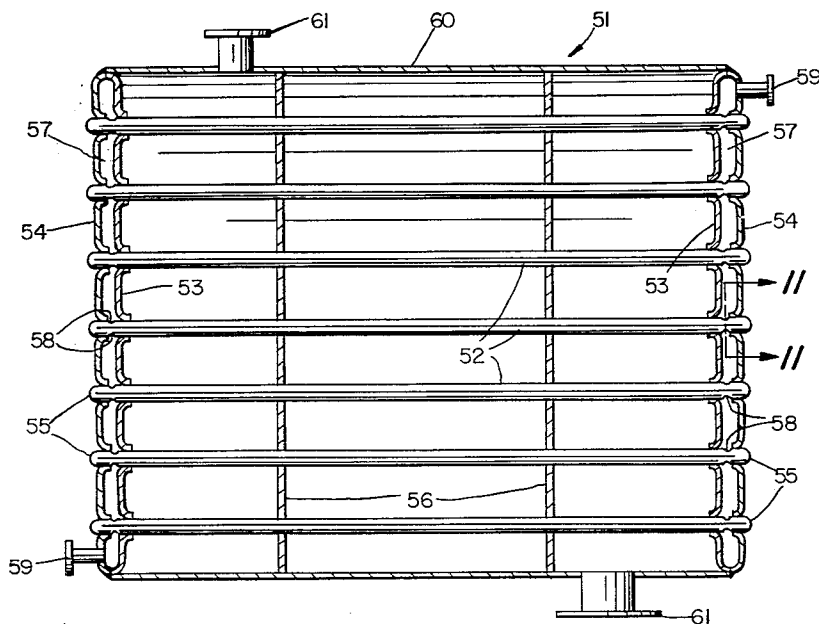


Fig. 10

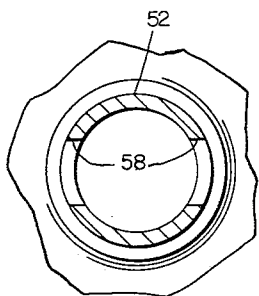


Fig. 11

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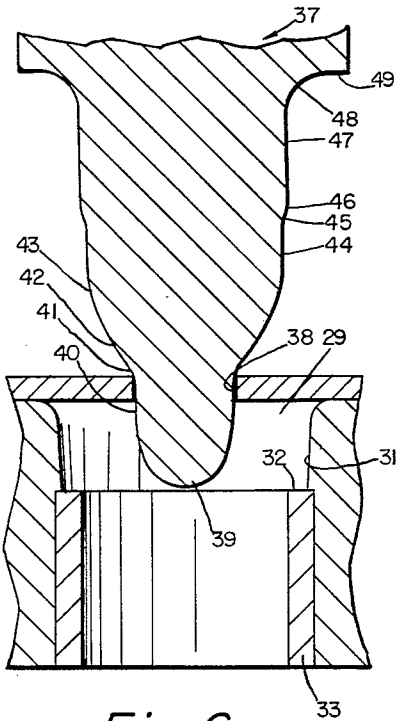


Fig. 6

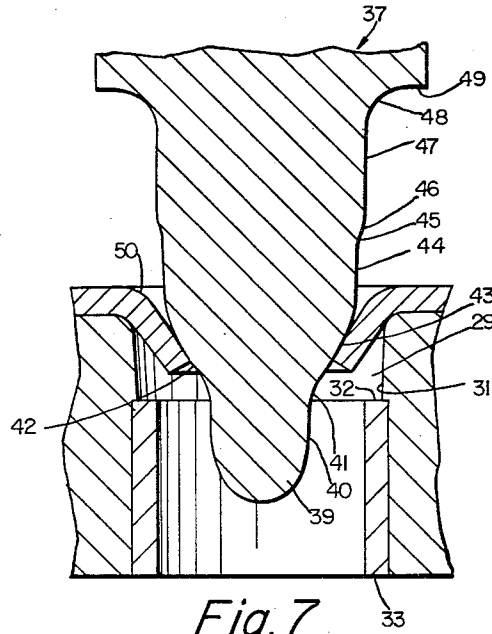


Fig. 7

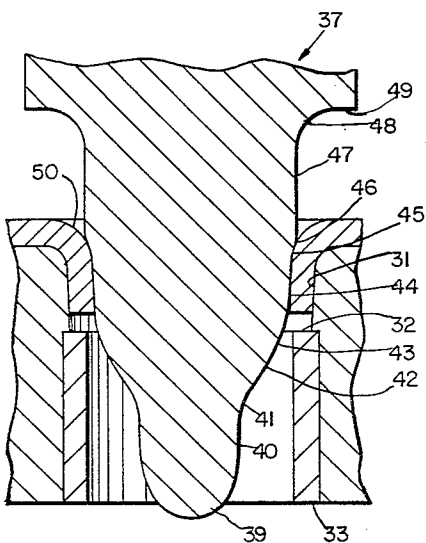


Fig. 8

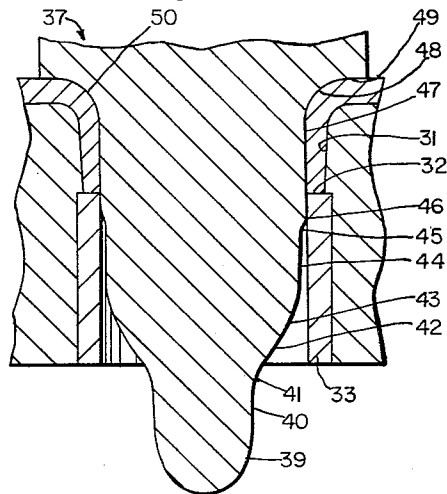


Fig. 9

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HEAT EXCHANGER APPARATUS

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3 Claims. (Cl. 165-153)

The present invention relates generally to heat exchanger apparatus, such as tubular condensers and the like, and more particularly to an improved tube sheet for such apparatus. Our invention is particularly directed to the pressure-type of apparatus in which the fluid media employed in the heat transfer are under greater-than-atmospheric pressures.

In such tubular condenser-type apparatus, for example, it has heretofore been the practice to use tube sheets having a minimum plate thickness of one-half inch with increased thickness being in common use, dependent upon the particular pressures for which the apparatus is designed. Various metals and alloys are used for the tube sheets and physical and dimensional standards have been established by professional and industrial associations based upon known design and manufacturing techniques.

It is the primary object of our invention to provide a heat exchanger apparatus having an improved tube sheet structure which is relatively thin and which is less costly to manufacture and assemble.

Another object of our invention is to provide an improved design of heat exchanger apparatus utilizing the improved tube sheet.

Other objects and advantages of our invention will be apparent during the course of the following description.

In the accompanying drawings forming a part of this specification and in which like numerals are employed to designate like parts throughout the same,

FIG. 1 is a view in side elevation of the tube bundle of a heat exchanger apparatus embodying our improved tube sheet.

FIG. 2 is an end view of the improved tube sheet as viewed from the left hand side of FIG. 1.

FIG. 3 is an enlarged fragmentary cross-sectional view taken as indicated on line 3-3 of FIG. 2 and showing the detail of one of the tube sheet openings.

FIG. 4 is a diagrammatic representation of the lower die shoe of a type of forming die which may be utilized to produce the flanged openings in the tube sheet.

FIG. 4a is a diagrammatic representation of the upper die.

FIG. 5 is a view showing the novel form of punch employed in forming the flanged openings.

FIGS. 6, 7, 8 and 9 show the progressive steps in the extrusion and coining of the tube sheet openings.

FIG. 10 is a cross-sectional view of a heat exchanger apparatus in which the tube sheet and shell are unitized.

FIG. 11 is a cross-sectional view taken on line 11-11 of FIG. 10.

Referring more particularly to FIGS. 1-3 of the drawings, we have shown a part of a heat exchanger apparatus consisting of a plurality of tubes 20 of uniform length, the opposite ends of which are secured to end plates or tube sheets 21 and 22. Intermediate the end plates 21 and 22, a series of baffle plates 23 are mounted on the tubes. The baffle plates 23 serve the dual purpose of defining an extended path of flow for the fluid medium, as well as serving to maintain the tubes in uniformly spaced relationship.

The end plates may be of the stayed type or of the floating type, both of which types are known in the art. However, our improved tube sheet can be utilized with either type and we have shown the end plate 21 as being

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of the stayed type and the end plate 22 as being provided with a circumferential flange 24, as is customary in the floating type.

As best seen in FIG. 2, the surface of the end plate or tube sheet 22 is provided with a plurality of closely-spaced openings 25 which correspond in number to the tubes 20 and are only slightly larger in diameter than the tubes which are received therein and extend proximate to the surface of the tube sheet. In contrast to the heavy plate thicknesses of tube sheet heretofore customarily utilized, the tube sheet, in accordance with our invention, is considerably lighter. Depending upon the spacing between tube centers, the diameter of the tube, and the magnitude of the external and internal pressures to which the tube sheet will be subjected, the tube sheet will have a thickness over the range of 22 ga. to 10 ga. for high strength ferrous metals and from 20 ga. to 8 ga. for non-ferrous alloys, thus being well below plate thickness.

As shown in FIG. 3, the relative thinness of the tube sheet does not result in any injurious reduction in the depth of the tube sheet opening or the length of the bearing surface between the tube and the opening, as this is effectively and sufficiently provided by a flange 26 which is extruded from each of the openings 25. The ends of the tubes 20 are secured in the openings 25 by brazing and may be further secured by rolling or flaring the ends, as at 27.

A form of die and punch for extruding or flanging the openings of the tube sheet is diagrammatically shown in FIGS. 4 and 4a. The lower die shoe 28 is provided with a series of forming cavities 29 which are spaced from each other on a center-to-center distance which is equivalent to exactly twice the center-to-center spacing desired in the finished tube sheet. A series of clearance cavities 30 are also provided, the pattern of arrangement of the cavities 29 and 30 being such as will correspond to the pattern desired in the tube sheet, and each pair of forming cavities 29 having a cavity 30 interposed between them so that the cavities 29 will not lie adjacent each other. It will be understood that the cavities 29 may be spaced from each other at three times the center-to-center distance, or such other whole number multiple as is considered desirable. In order to obtain the requisite form of tube opening 25 and maintain the openings in closely spaced relationship, it is preferable that the forming cavities 29 be disposed in the staggered pattern described.

The wall of the cavity 29 is tapered as at 31 to provide a slight angle, in this instance, 6° included angle, which taper extends to an annular shoulder 32 provided by a hardened cylindrical sleeve or bushing 33 which is fixedly mounted in the cavity.

The lower die 28 is also provided with guide posts 34 which cooperate with openings 36 in the upper die shoe 35 to maintain the dies in proper alignment. The upper die shoe 35 also carries a series of punches 37 which are adapted to register with the forming cavities 29. The lower die is adapted to be mounted on the lower platen of a hydraulic press, and the upper die shoe 35 is adapted to be secured to the power ram of the press.

The novel form of punch 37 is shown in detail in FIG. 5. It is designed to form and coin the flange 26 without introducing a pressure shock and consequent granular fracture at the edges of the opening 25. This is accomplished, without a slowdown in the downward stroke of the press ram, by modulating the flanging punch contour so that it comprises a series of sequential forming steps which take place successively throughout the stroke, without any concentration of impact at any one point.

The structure and operation of the punch 37 is best understood by considering FIGS. 5 and 6 through 9 together. The tube sheet is pre-drilled or pierced to pro-

vide a pilot hole 38 corresponding to each tube opening 25. The pilot holes must be accurately located and spaced from each other on the proper center-to-center distance. The size of the pilot hole 38, inasmuch as it represents the removal of some metal stock, determines the maximum length of flange 26 which can be formed. We have found that, for best results, the diameter of the pilot hole should be from $\frac{1}{3}$ to $\frac{1}{2}$ the finished inside diameter of the flanged hole, and, where it is possible to do so, optimum results can be obtained if the pilot hole has a diameter which is close to 0.45 times the inside diameter of the flanged hole 25.

The punch 37 is provided with a pilot portion, the function of which is to assure perfect concentricity during the flanging operation. The pilot portion includes a rounded bullet-shaped nose or entry cone 39 which leads the punch into the pilot hole 38; and a straight cylindrical section 40, which has a diameter just slightly smaller than that of the pilot hole 38. In FIG. 6, the punch 37 is shown in a position where the pilot portion has entered the pilot hole 38 and is centered therein by the guiding action of the section 40. The length of the section 40 should be approximately $1\frac{1}{2}$ times the thickness of the tube sheet.

The second step of the punch 37 initiates the flanging action as shown in FIG. 7. The section 40 of the punch is blended, by means of a highly polished fillet 41 of large radius, into a tapered section 42, the included angle of which may range from 30° to 60° depending upon various factors, such as the hardness and thickness of the tube sheet material. The tapered section 42 modulates the impact of the punch 37 and prevents granular fracture of the tube sheet material so that this type of hazardous latent defect in the tube sheet is obviated or, at least, greatly minimized. The tapered section is blended into the third step of the punch by a smooth and polished convex section 43 of large radius which serves to reduce the friction on the flange and serves as a traveling fulcrum in distributing the forming pressure as the punch descends.

The third step of the punch serves the purpose, as shown in FIG. 8, of sizing the outside diameter of the flange by conforming it with the tapered wall section 31 of the forming cavity 29. A tapered section 44 of the punch parallels the tapered wall section 31 and is spaced therefrom by the thickness of the tube sheet stock, so that the flange is formed to the wall 31, but no swaging of the material occurs. The section 44 of the punch is blended by means of large radius fillets 45 and 46 into the fourth step of the punch 37. The large diameter of the section 44 is less than the finished diameter of the flanged opening. The radius of the fillet 46 is desirably equal to the radius of the finished opening 25.

The fourth step of the punch accomplishes the final sizing and coining of the flanged opening. This is shown in FIG. 9. The fourth step of the punch 37 includes a straight cylindrical section 47 which is of the same diameter as the finished opening 25 and approximately $\frac{1}{3}$ longer than the length of the flange. As the section 47 of the punch moves downwardly, a swaging action occurs which reduces the thickness of the flange and sizes it to the desired internal diameter. At the same time, the flange stock is extruded or stretched to increase its length toward the shoulder 32 in the forming cavity 29. The straight section 47 is blended by means of a 90° fillet 48 into a horizontal base section 49 of the punch, which has a diameter approximately $1\frac{1}{2}$ times greater than the inside diameter of the opening 25. In the completion of the press stroke, the base section 49 forces the tube sheet material downwardly into engagement with the shoulder 32, thus providing a coining operation for accurate and uniform sizing of the flange 26, while at the same time accurately sizing the radius portion 50 at the mouth of the opening 25.

It will be understood that the foregoing forming, extruding and coining sequence occurs simultaneously as to each

of the plurality of punches 37 which are carried by the die. The tube sheet is then indexed or shifted to extrude the flanges 26 on an additional plurality of openings and this procedure is continued until the desired pattern of tube openings 25 is completed. The clearance cavities 30 of the die accommodate the previously formed flanges 26 during the successive indexing of the tube sheet. The tube sheet is then stress-annealed and is then straightened in a power press while it is still hot.

The resulting tube sheet or end plate 22 provides a pattern of very closely-spaced flanged openings 25 of extremely accurate and uniform dimension, without any granular fracture resulting from the extrusion process. The tapered section 42 of the punch 37 modulates the pressure shock which might otherwise result from the rapid press action and the independent two-stage processing of adjacent openings 25 permits the openings to be in close proximity (within one-eighth inch of each other) without sacrifice of strength. The extruded and coined flange opening 25 provides the necessary depth of opening for the effective securement of the tubes 20 while at the same time permitting the use of sheet metal gauges and efficient power press operations in the fabrication of the tube sheet. This procedure eliminates the considerable and costly machining operations now utilized in producing end plates and likewise make unnecessary the use of heavy plates for such end plates.

In FIGS. 10 and 11, we have shown a modified form of heat exchanger apparatus 51 in which the tube sheet of our invention is utilized to provide an integrated and unitized structure in which the tube sheets or heads are welded to the shell of the apparatus. This arrangement provides a strong and rigid structure which utilizes less material and is far less costly than known forms of heat exchanger apparatus of similar character and function.

The apparatus 51 includes a plurality of spaced tubes 52 which are supported adjacent their ends by spaced heads 53 and 54. The ends 55 of each tube 52 project beyond the external head 54 and are closed or sealed. The tube bundle may be further supported, intermediate its ends, by a plurality of support plates 56.

Each of the heads 53 and 54 is provided with the required pattern of flanged tube openings 25 which are formed in the tube sheet in the manner heretofore described. The space between each set of heads 53 and 54 serve as a manifold 57 for the fluid media used in the heat transfer. Passage of the fluid media into and out of the tubes is provided by dimetrically-opposed apertures 58 in the wall of each tube 52 in an area which is exposed to the manifold 57. Entry and exit nozzles 59 for the fluid media are secured to the external head 54.

Each pair of heads 53 and 54 are connected, as by welding, at their periphery to a shell 60 which encloses the tube bundle. Entry and exit nozzles 61 are secured to the shell 60 externally thereof.

The apertures 58 in each tube 52 are of such combined size as to equal or exceed the cross-sectional area of the tube 52, thus providing ample flow passage for the fluid media. The tubes are secured to the heads by brazing. It is to be noted that the radius portion 50 at the mouth of the flanged opening 25 provides a capillary area for obtaining penetration and bond during the brazing process.

The foregoing described form of heat exchanger not only utilizes the advantages of our novel form of stamped tube sheet, but also provides an efficient and economical apparatus which eliminates much of the weight and many of the sealing problems which are encountered in the design and fabrication of high pressure heat exchangers.

It is to be understood that the forms of our invention, herewith shown and described, are to be taken as preferred examples of the same, and that various changes in the shape, size and arrangement of parts may be resorted to, without departing from the spirit of our invention, or the scope of the subjoined claims.

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Having thus described our invention, we claim:

1. In a heat exchanger apparatus, the combination of a casing structure comprising a shell and an integrated tube sheet assembly sealing each end of said shell, exit and entry means for fluid flow provided on said shell and communicating with the interior thereof, said tube sheet assembly comprising a pair of integrated spaced tube sheets defining a manifold chamber therebetween, a fluid flow inlet nozzle provided on one of said tube sheet assemblies and communicating with the manifold chamber thereof, a fluid flow outlet nozzle provided on the other of said tube sheet assemblies and communicating with the manifold chamber thereof, a plurality of tubes traversing said tube sheet assemblies and supported in predetermined spaced relationship thereby, each of said tubes having an inlet aperture provided therein in communication with said inlet manifold chamber and having an outlet aperture therein in communication with said outlet manifold chamber, and said inlet and outlet apertures defining the sole communication for fluid flow between said inlet and outlet manifold chambers.

2. A combination as defined in claim 1, wherein said inlet and outlet apertures are provided in the wall of each tube intermediate the ends thereof, and the ends of each tube are sealed and project beyond the exterior of the tube sheet assemblies.

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3. A combination as defined in claim 2, wherein each of said tube sheets is formed of sheet metal of a thickness in the range of 22 gauge to 8 gauge inclusive, said tube sheet being provided with integral flanged openings for securement of said tubes, and said flanges being of greater length than the thickness of said sheet metal.

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