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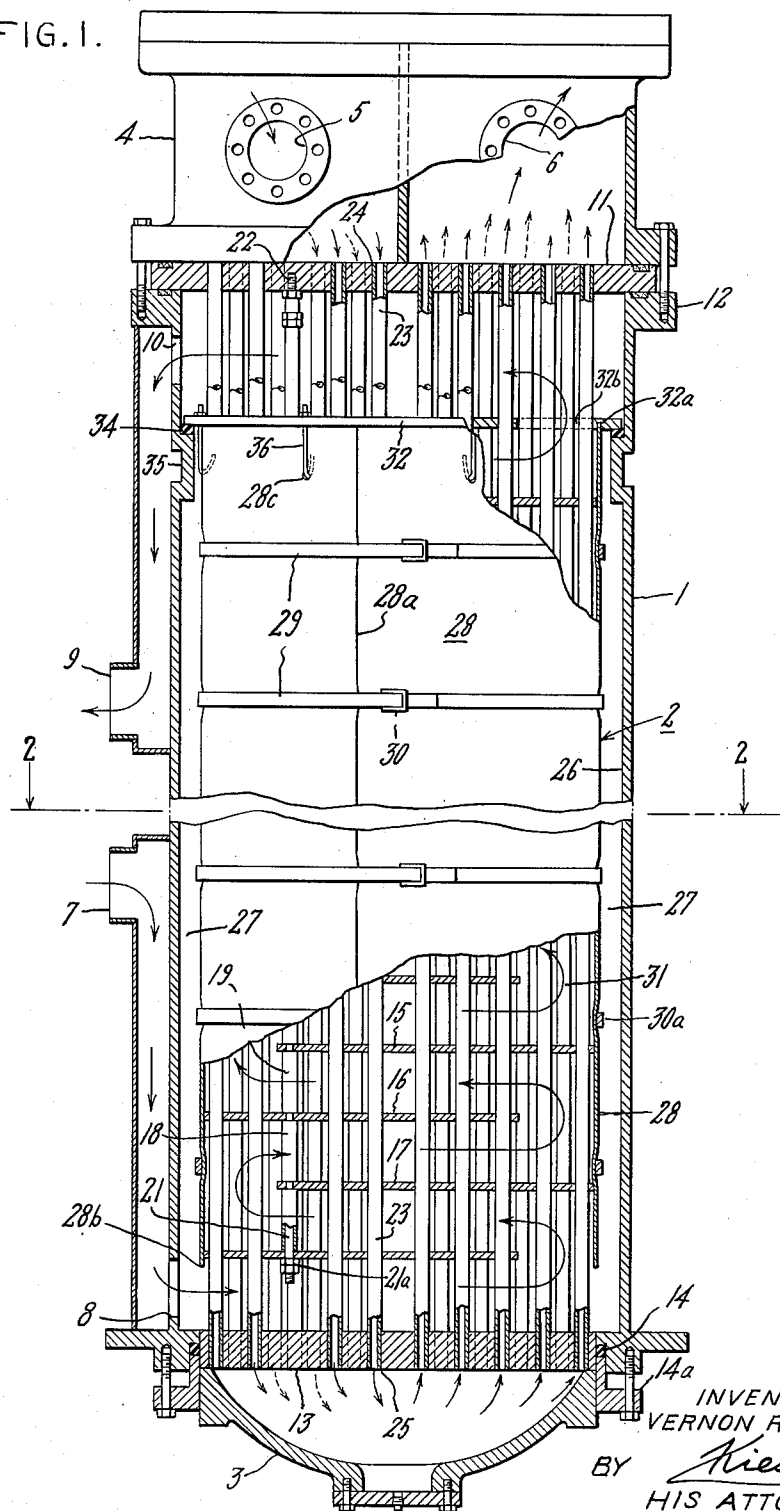
2,978,226

TUBE TYPE HEAT EXCHANGER

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2 Sheets-Sheet 1

FIG. 1.



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FIG. 2.

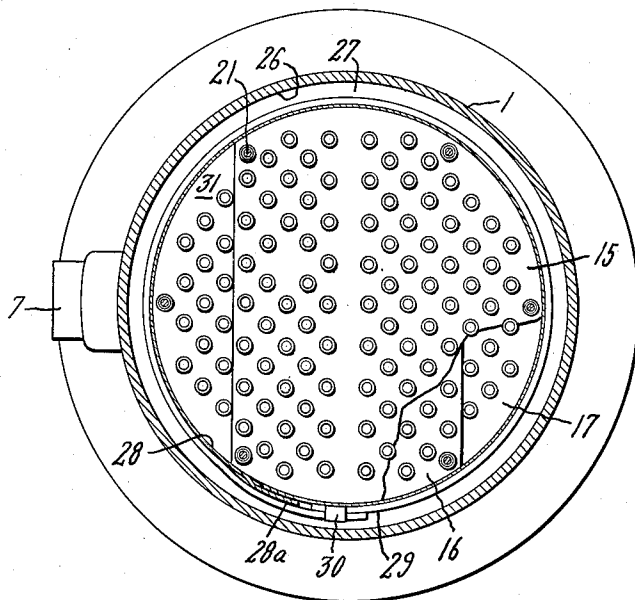
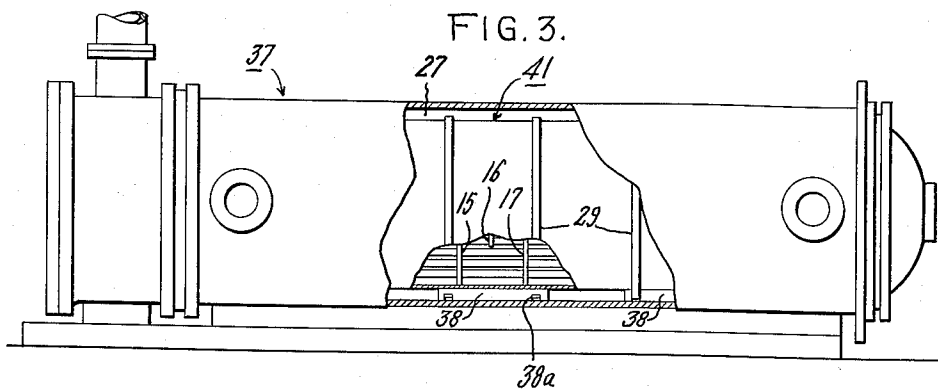


FIG. 3.



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TUBE TYPE HEAT EXCHANGER

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1 Claim. (Cl. 257—224)

This invention relates to "shell-and-tube" type heat exchangers and more particularly to an improved tube bundle and baffle arrangement for such heat exchangers having integrally insertable tube bundles.

In a shell-and-tube heat exchanger, it is preferable to provide for removal of the tube bundle from the shell for cleaning and maintenance of the tubes. In a tube bundle of the type where the tubes are secured to at least one tube sheet, it is generally necessary that the baffles, which are provided to direct the fluid back and forth among the tubes, be secured on the tubes during assembly of the tube bundle so that the baffles and tubes are removable as a single unit.

In one form of construction, where the outer casing is cylindrical, the baffles often take the form of disks having openings through which the tubes pass and having portions cut from their peripheries to allow the passage of the fluid from one side of the baffle to the other. The baffles described are generally termed segmental and are held spaced apart from one another by tubular spacers which are placed on longitudinally running "stay rods" during assembly. The baffles are arranged so that the cutout portions alternately face opposite sides causing the fluid to alternate from one side of the casing to the other through the tubes as it makes its way from one end of the heat exchanger to the other. Although the transverse baffles described are segmental, an equivalent arrangement would utilize the so-called "disk and donut" baffles which consist of alternate hollow disks and under-size disks.

There must, of course, be a pressure differential causing the fluid to flow around the cutout portions of the heat exchanger baffles. Any leakage, therefore, around the circular periphery of a segmental baffle, between the baffle and the shell, will reduce the efficiency of the heat exchanger both by reducing the flow velocity of the fluid along the desired path and by allowing some of the fluid to take the leakage path without undergoing heat transfer with the other fluid in the tubes. Some mechanical clearance between the baffles and shell is necessary, on the other hand, in order to slide the baffled tube bundle into the shell.

The usual method for maintaining close engagement of the baffle plates with the inner wall of the casing to minimize leakage is to subject the rough outer casing to a boring operation to provide a machined finish on the inside of the casing to control clearance dimensions between baffle and casing. This naturally reduces the wall thickness of the casing, and extra metal must be provided in the wall thickness to allow for this machining. Also, since the boring is done internally and requires a high degree of accuracy, special machinery is necessary to accomplish the boring. In cases where it might be desirable to incorporate the heat exchanger into part of a larger structure, this is often not feasible because of the necessity of performing the boring operation on the much larger structure in order to accommodate the baffled tube bundle.

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Accordingly, an object of the present invention is to provide an improved removable tube bundle assembly for a shell-and-tube heat exchanger which removes the necessity of machining the shell interior to provide for close engagement with the baffles.

Another object is to improve the efficiency of disk-type baffles by providing a flow containing duct which tightly engages the peripheries of the baffles.

A still further object is to increase the flexibility of overall station layout including heat exchangers by providing a removable tube bundle which does not require a bored shell and which therefore permits the shell to be incorporated in a larger structure.

Another object is to provide an improved baffled tube bundle assembly which achieves important economies of manufacture by eliminating costly machining operations.

The subject matter which I regard as my invention is particularly pointed out and distinctly claimed in the concluding portion of the specification. My invention, however, both as to organization and method of practice, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawing in which:

Fig. 1 is an elevation view, partly in section, of a tube-type removable bundle heat exchanger incorporating my invention;

Fig. 2 is a cross-section taken along the line 2—2 in Fig. 1; and

Fig. 3 is an elevation, partly in section, of a horizontal tube heat exchanger incorporating my invention.

The invention is practiced by providing a tube-type heat exchanger with an outer casing or "shell" defining an ample clearance around the periphery of the tube bundle baffles for convenience of assembly and to allow for any variation in the dimensions of the shell, and wrapping around the tube bundle a thin shroud of sheet material so as to tightly engage the outer edges of the baffles. Special sealing means are provided to prevent fluid flow through the annular clearance between the "wrapper" and the shell. In this respect, the casing or rough shell becomes the pressure or fluid-containing vessel and the shroud conducts the flow of fluid over the tubes.

Referring now to the drawing, Fig. 1 shows a heat exchanger having an outer pressure shell 1 containing a tube bundle shown generally at 2. The pressure shell 1 is sealed at the bottom end by a "return header" 3 and at the top end by an "inlet-outlet header" 4 having inlet and outlet ports 5 and 6 respectively. Incorporated into the pressure shell casting are inlet conduit 7 admitting fluid to the interior of the shell through port 8 and outlet conduit 9 which is supplied by port 10 at the top of the pressure shell. The tube bundle 2 is held in position in the shell by the upper tube sheet 11 which is secured rigidly between the header 4 and a top flange 12 on the shell. The lower tube sheet 13 is held coaxial with the shell 1 and allowed to "float" to provide for differential thermal expansion by a gland seal 14 and retaining ring 14a. Disposed between the upper tube sheet 11 and the lower tube sheet 13 are horizontal baffles 15, 16, 17, etc., which are maintained in spaced relationship by means of spacer tubes 18, 19 threaded on a "stay rod" 21 running longitudinally in the heat exchanger. The upper end of the stay rod 21 is threaded into the upper tube sheet 11 as seen at 22, and the lower end is threaded to receive nuts at 21a.

The tubes of the heat exchanger, one of which may be seen at 23, run the entire length of the heat exchanger and are rigidly secured to the upper and lower tube sheets at 24 and 25 respectively by expanding the tube ends in the conventional manner. The baffles, which are

generally disk-shaped and have a segment removed to allow the passage of the heat transfer medium, are alternated to constrain the fluid to take a tortuous path as it flows through the heat exchanger, as indicated by the flow arrows in Fig. 1.

Under one conventional method of construction, the baffles would normally be fabricated having a diameter slightly greater than the diameter of the rough interior surface 26 of the pressure shell. This inner surface 26 would then be machined by boring the interior of the pressure shell to remove just sufficient metal to allow the baffles to slide into the pressure shell, yet defining a minimum clearance to reduce leakage. A compromise has to be made to insure as tight a fit as possible and yet not to allow excessive leakage between the baffle and the pressure shell.

Using my improved construction, the pressure shell 1 is enlarged to provide a generous clearance space 27 between the outer periphery of the baffles 16, 17 and the pressure shell 1. This clearance space 27 may be seen also by reference to Fig. 2 of the drawing, and is made large enough to allow for any variation due to fabrication and surface roughness and to allow for easy removal of the tube bundle.

In keeping with the invention, a shroud member 28, which consists of a thin flexible sheet of metal, is "wrapped" around the tube bundle so that the edges overlap as seen at 28a of Fig. 2. This shroud 28 is drawn tightly into engagement with the radially outer portions of baffles 15, 16, 17, etc., and is secured in place by means of peripheral bands 29.

The shroud 28 is sufficiently thin and flexible that it will deflect slightly to follow the contour of the circumferential portions of the baffles. Care must be taken, however, not to unduly stress the shroud 28 with the bands 29 so that it deflects to constrict the flow passage 31 which has been formed by removing a segment from the baffle. The shroud may consist, for example, of a sheet of stainless steel, of a composition known in the trade as "Type 304" and of a thickness of about .019 inch. The steel bands, which hold the shroud 28 in position on the baffles may be $\frac{1}{16}$ inch by $\frac{3}{8}$ inch stainless steel banding which is subjected to tension and secured with a deformable clip 30, or in any other suitable manner. It is preferable to locate the band 29 intermediate of the baffles, as seen more clearly at 30a, in order to fully utilize the flexibility of the thin shroud material to conform to the circumference of the baffle members.

The shroud 28 is located longitudinally at the upper end by an annular groove 32a on a special baffle plate 32. J bolts 36, having curved portions passing through suitable apertures 28c in the shroud, hold shroud 28 securely in the annular recess 32a. The shroud 28 tightly contacts the inner periphery of the annular groove 32a.

In order to prevent the flow of fluid in the clearance space 27 between the shroud 28 and the shell 1, a soft gasket 34 is provided between the special baffle plate 32 and an annular projection 35 on the interior of the pressure shell 1. The gasket 34 must be of soft material to compress and form a seal when tube sheet 11 is bolted in place between flange 12 and header 4 and to compensate for the slight movement due to differential thermal expansion which occurs between upper tube sheet 11 and special baffle plate 32. The shroud 28 extends beyond the bottom baffle as shown at 28b but does not extend to the tube sheet 13. Sufficient space is left between the extreme extension 28b of the shroud 28 and tube sheet 13 for entrance of the fluid to the interior of the shroud.

It will be observed that fluid entering port 8 is also free to fill the clearance space 27 but is not permitted to flow out through the top of this clearance space by virtue of the gasket 34 which forms a seal between the special baffle plate 32 and the shell 1. Thus the pressure will be substantially equalized on both the in-

side and outside of the shroud, allowing the shroud to be of a relatively light construction. The fluid entering the shroud 28 at the bottom is constrained to flow inside the shroud, on the other hand, following the flow path shown by the arrows past baffles 15, 16, 17, etc. Due to the tight engagement of the shroud with the baffles, a tight and efficient seal is formed which prevents substantial leakage and promotes efficient flow.

Fig. 3 shows a heat exchanger 37 similar to that of Fig. 1, with the exception that it is designed to operate in a horizontal position. Inasmuch as the baffles 15, 16, 17 do not touch the side wall of the shell 1 with my improved tube bundle assembly, it is desirable to incorporate supporting shoes 38 in order to support the tube bundle at points intermediate the tube sheets. These shoes 38 are held in place by the same straps 29 that hold the shroud in position around the tube bundle. Recesses 38a are provided in the outer face of each shoe, in order to accommodate straps 29 and the radially outer and inner surfaces of the shoe are contoured to conform with the interior surface of the shell and with the baffle plates.

By utilizing the shoes 38, the tube bundle 41 of Fig. 3 may be slid into the shell from one end while it is in a horizontal attitude, being supported by the shoes 38 as it is inserted. In the case of very long heat exchangers, this ability to insert the tube bundle in the horizontal position is much preferred. The use of the shoes also enables vertical heat exchangers, such as shown in Fig. 1, to be assembled in the horizontal position if desired. The shoes 38 are merely strapped to the side of the bundle; the heat exchanger is assembled in the horizontal attitude, and then turned upright to its vertical position. Since there is no flow in the clearance space 27, the presence of the shoes 38 does not affect the operation of the heat exchanger.

The operation of my improved removable tube bundle for a heat exchanger using the baffle shroud may now be described. The tube bundle is assembled initially in the conventional manner with a horizontal rack or other supporting means to hold the components during assembly. Stay rods 21 are threaded into the tube sheet 11, and the baffles 15, 16, 17 are threaded on the stay rods at the same time separating them with tubular spacers 18, 19. Then tubes 23 are threaded through the holes in the baffle plates and into the holes in the tube sheet 11 with a few inches extending beyond the face of tube sheet 11. The lower tube sheet 13 is put in place on the supporting rack and the tubes are pushed back to enter the holes in tube sheet 13. The assembly is aligned and stay rods 21 adjusted by lightening nuts 21a to obtain correct relationship between parts before expanding the tube ends in the tube sheets. At this point the tube bundle resembles in most respects the tube bundle of the type used in the conventional shell-and-tube heat exchanger having a removable tube bundle.

Next, in the preferred method of assembly, the shroud 28 is wrapped around the bundle and is held loosely in place by temporary retaining bands. The wrapped shroud 28 is then adjusted axially so that the end toward the special baffle 32 is fitted into the annular recess 32a, and at the other end, the wrapped shroud will extend over the bottom baffle sufficiently far to permit adequate support to the shroud by this last baffle. Next, the stainless steel binding bands 29 are applied at intervals along the shroud 28, pulling the shroud tightly against the baffles and securing bands 29 with clips 30. In the preferred method of assembly, the banding is carried out utilizing a standard banding tool such as used in shipping areas for banding crates and similar objects. The final shroud assembly is held against the special baffle 32 by J-bolts 36. The assembled tube bundle is then ready to be inserted into the shell.

If desired, in order to increase the efficiency of the

shroud, an application of solder or sealing compound impervious to the fluid being circulated may be made along the longitudinal overlap 28a of the shroud in order to seal the overlap. However, since the shroud is surrounded by fluid at substantially the same pressure, only negligible leakage will occur at this point if solder or other sealing means is not used.

The shroud may be removed from the tube bundle for cleaning the tubes or for replacement of a tube. First the J-bolts are loosened and the binding bands 29 are severed and the shroud allowed to unwrap from the tube bundle. The shroud may be reused, it being only necessary to supply new binding bands 29 and clips 30.

In the heat exchanger shown, the cooling fluid, water in this case, enters at conduit 5 at the left-hand top side of the heat exchanger of Fig. 1, travels downward through the tubes, reverses direction in the reverse header 3, and travels upward through the tubes to exit through conduit 6. The fluid being cooled, lubrication oil here, enters through inlet conduit 7, flows downward to enter the pressure shell at port 8 and flows around the end 28a of the shroud into the tube and baffle portion. It may be seen that if the clearance space 27 were perfectly airtight, an air pocket would be trapped between the shroud and the shell. Some leakage occurs, however, so that this clearance space will become completely filled with oil. The oil flows along the tortuous path formed by the baffles 15, 16, 17 to emerge through an opening 32b in the special baffle plate 32, and leaves the pressure shell through conduit 9. During its travel through the shroud, the oil is restrained from leaking between the arcuate portions of the baffle plates and the surrounding shroud as was the case with previous constructions where a clearance was necessary between the baffle and the shell in order to insert the tube bundle into the shell. Here, due to the tight engagement of the shroud with the transverse baffle plates, little leakage can occur and the oil must flow through the desired path. This promotes efficient heat transfer because no oil is allowed to bypass the cooling water tubes. It can be seen that any bypassing fluid which is not cooled would increase the temperature of the cooled portion of the fluid when eventual mixture occurs. Since the actual amount of bypassing in the conventional shell-and-tube heat exchanger is an uncertain quantity, the elimination of this uncertainty allows a more accurate prediction of the heat removal capacity of the heat exchanger which, in turn, leads to more economical designs.

Since practically the same pressure exists on both sides of the shroud 23, it acts primarily as a duct for controlling the flow of the fluid and needs to withstand no appreciable pressure differential. It may, therefore, be relatively thin in order to allow flexible assembly and to allow it to conform to the arcuate contour of the baffle plates.

The many advantages of my improved removable tube bundles should now be apparent. Due to the ample clearance 27 between the tube bundle and the shell, an increased interchangeability between different tube bundles and shells is made possible. Rather than each tube bundle being "tailored" to a particular shell by careful machining, this ample clearance provides for replacement of one tube bundle with another tube bundle, without re-machining the shell.

Because no added casing wall thickness must be provided to compensate for metal removed during fitting of the tube bundle, this reduction in wall thickness permits

a net saving of shell metal, even though the diameter of the shell must be increased by the amount of the generous clearance 27.

In addition to this saving in metal, perhaps even more significant is the great saving in labor and machining by elimination of the necessity for boring the inner surface of the large casing 1, and the careful fitting of the tube bundle in the casing, necessary with prior constructions. While the preferred embodiment described utilizes only a single shroud member, it will be realized that, in the case of a fairly long heat exchanger, the handling problem would increase. Therefore, it may be convenient to use a number of longitudinally overlapping shrouds which are applied in the same manner as the single shroud described, each of which covers only a portion of the total tube bundle length. Since the pressure differential is slight, the series of shrouds will function much as a single shroud with slight leakage. Solder or caulking, however, may improve the efficiency somewhat.

While there has been described what is at present considered to be the preferred embodiment of the invention, it will be understood that various modifications may be made therein, and it is intended to cover in the appended claim all such modifications as fall within the scope of this invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

A shell-and-tube heat exchanger comprising a cylindrical pressure shell defining an inlet opening at one end and an outlet opening at the other end, a removable tube bundle including a plurality of tubes held by first and second longitudinally spaced tube sheets and a plurality of longitudinally spaced transversely extending baffle plates disposed on said tubes, said baffle plates having first peripheral portions substantially concentric with and radially spaced from said cylindrical pressure shell and second portions defining a fluid flow path, means to support said tube bundle coaxially within the pressure shell, shroud means including at least one imperforate flexible sheet having a length less than the distance between said tube sheets wrapped around the tube bundle and engaging the first peripheral portions of the baffle plates, said sheet being held by the baffles in non-engaging relationship with either tube sheet to provide for differential thermal expansion, circumferential tension means comprising straps encircling and securing said shroud means around the tube bundle in sealing engagement with the peripheral portions of said baffle plates, and sealing means disposed adjacent said casing outlet opening and obstructing flow of fluid through a substantial radial clearance space extending longitudinally and defined between the inner periphery of the cylindrical pressure shell and the shroud means, whereby the shroud means defines the flow path for all the fluid over the tubes as directed by the baffle plates and said radial clearance space facilitates insertion of the tube bundle assembly into the casing.

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