Jan. 22, 1963 J. W. BROWN, JR., ETAL 3,074,480

HEAT EXCHANGER

Filed Sept. 14, 1960

2 Sheets-Sheet 1

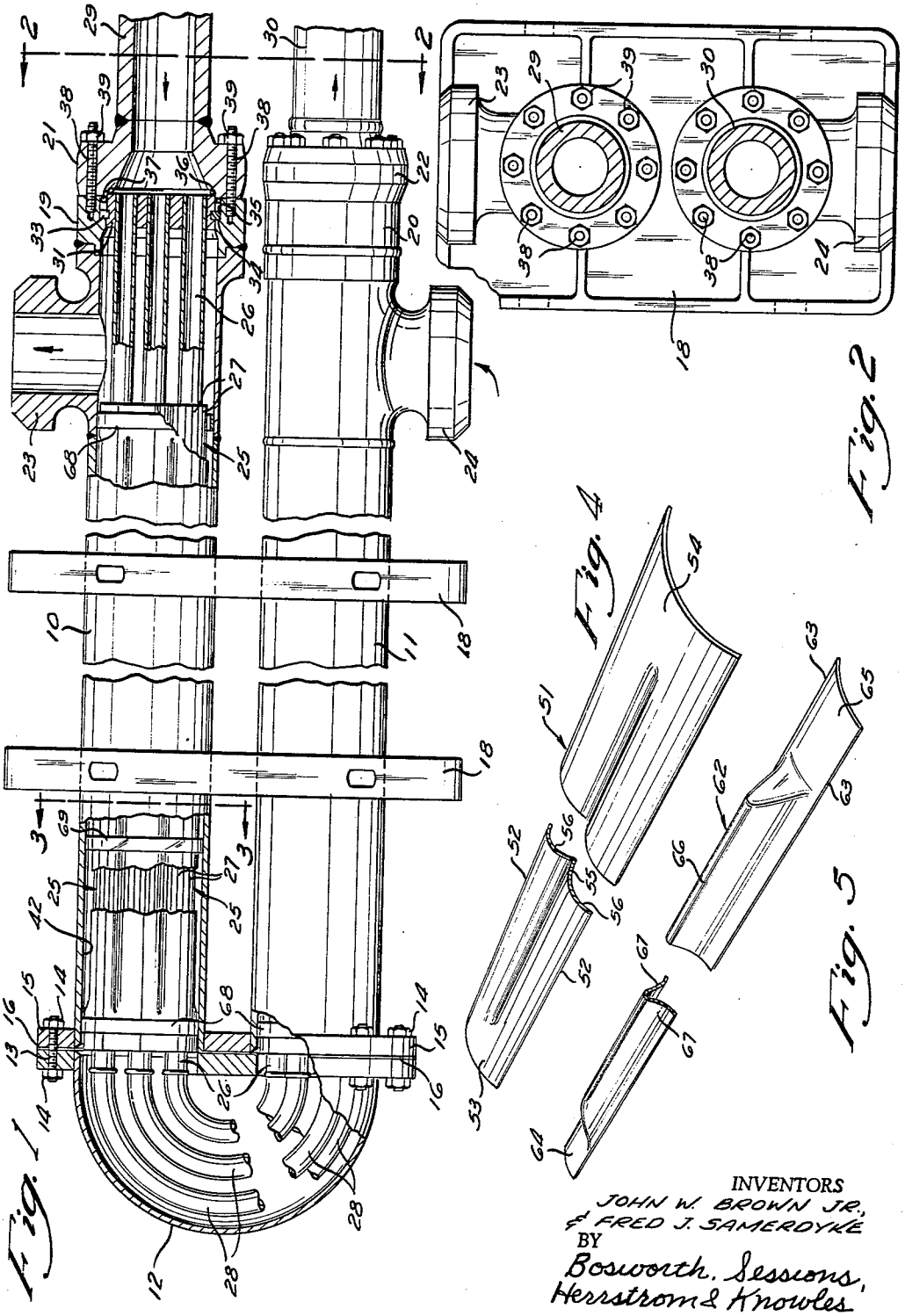

Fig. 1

Fig. 2

Fig. 4

Fig. 5

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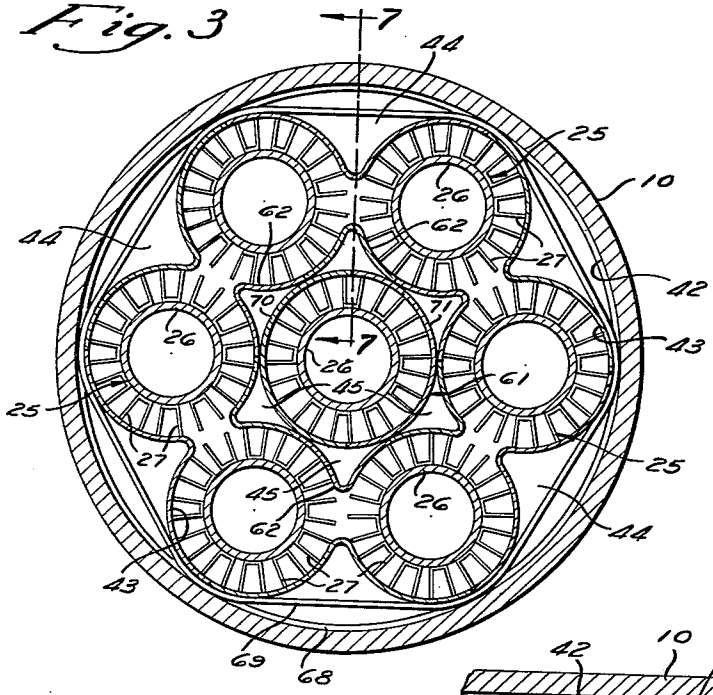
2 Sheets-Sheet 2

Fig. 3



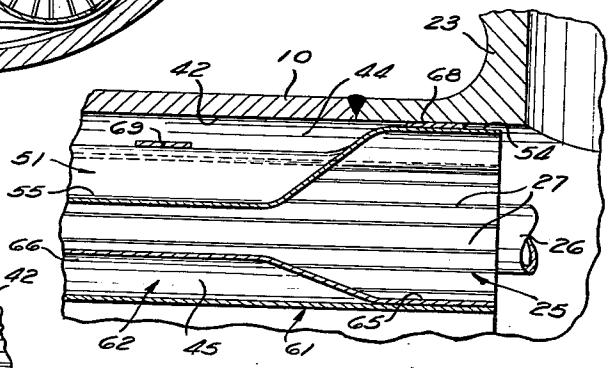


Fig. 8

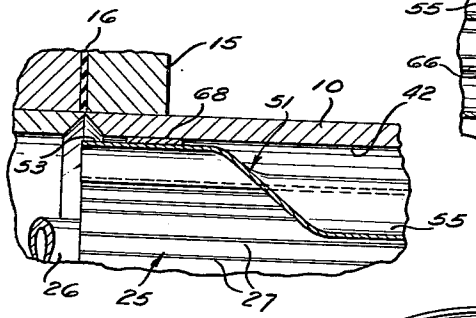


Fig. 7

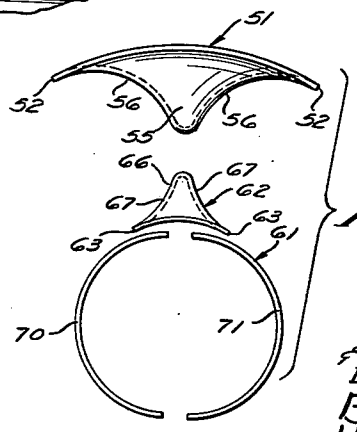


Fig. 6

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HEAT EXCHANGER

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11 Claims. (Cl. 165—154)

This invention relates to heat exchangers. More particularly it relates to heat exchangers of the type embodying an elongated shell within which is disposed a bundle of heat transfer tubes having longitudinally extending radial external heat transfer fins.

In heat exchangers of this type, one of the heat exchange fluids flows longitudinally within the shell and outside of the finned tubes in the bundle, while the other heat exchange fluid flows within the finned tubes, the heat transfer fins being provided on the tubes to increase the rate of heat exchange between the fluids. A multiplicity of finned tubes, positioned as closely together as possible without intermeshing of fins on adjacent tubes, is used to obtain large heat exchange capacity in a small space. For strength and economy of manufacture the shell is almost invariably made of circular cross section. Since the cross section of the periphery defined by the outer edges of the fins on the bundle of finned tubes is made up of the outer arcs of the tangentially related circles defined by the outer edges of the fins, it is obvious that recesses of substantial cross sectional area are left between such outer periphery of the bundle and the inner surfaces of the shell, this even though the diameter of the inner surface of the shell is as small as feasible; these peripheral recesses take the form of valleys or troughs of substantial width and depth defined by the outer peripheral portions of adjacent finned tubes and by the adjacent inner surface of the shell. Recesses of substantial cross sectional area also exist within the bundle between the tangentially related circular peripheries defined by the outer edges of the fins on the adjacent tubes.

In the absence of the present invention these peripheral and internal recesses, which extend throughout the length of the fins in the bundle, permit a substantial portion of the fluid flowing outside of the tubes to pass through the shell at such a distance from the fins on the tubes that little if any heat exchange can take place between such fluid and the fluid flowing within the tubes. This reduces the efficiency and increases the size and cost of a heat exchanger required for a given duty. This undesirable by-passing or short-circuiting of the spaces between the fins where heat transfer is most effective is intensified by the surface resistances to fluid flow provided by the extended surface areas of the heat transfer fins. This results in particular disadvantages in the heating or cooling of highly viscous liquids, since the high viscosity of the liquid accentuates the flow resistance provided by the fin surfaces and causes a pronounced tendency for the viscous liquid to seek the wide passages provided by the peripheral and internal recesses, where resistance to flow is less, but where heat transfer is much less effective. Exceptional disadvantages occur in the cooling of highly viscous liquids, as is the practice with certain oils, asphalts or chemicals which after manufacture or processing must be cooled for safety, storage or transportation. In such case, the liquid is cooled the most which is

nearest the fins, where heat transfer is most effective. Since, however, the viscosity of this coolest liquid is highest, the resistance to fluid flow is thereby intensified, as is the tendency for warmer liquid of lower viscosity to bypass the fins and flow at a greater rate and quantity through the wider peripheral and internal passages providing less flow resistance. Consequently, in the absence of the present invention, cooling efficiency is decreased and larger or more heat exchangers are required to achieve a desired amount of cooling, with resulting increases in capital and operating costs.

In general, to achieve an even higher rate of heat transfer in a given length of heat exchanger, it is desirable that each finned tube of the bundle be part of a hairpin type tube comprising two straight finned tube sections joined at one end by a return bend. In the hairpin type of heat exchanger in which the present invention provides particular advantages there are two bundles of finned tube sections, each bundle being located in a separate shell section, both shell sections being connected by a return bend section containing the return bend portions of the hairpin tubes. To enable the heat exchanger to be easily assembled and disassembled for inspection, cleaning, and repair, it is desirable that the straight portions of each hairpin tube be connected at only one end to a conduit for the fluid passing through the finned tubes, the remaining portions of the hairpin tubes being free of connections to the shell which would prevent the group of hairpin tubes from being withdrawn as a unit from one end of the shell. The finned tube sections themselves should be readily accessible for cleaning after disassembly of the heat exchanger. These structural features and requirements that the heat exchanger be readily disassembled and assembled for inspection, cleaning and repair accentuate the difficulty of solving the problem of preventing passage of substantial portions of fluid through the large peripheral and internal recesses to avoid bypassing of the spaces between the heat transfer fins.

A general object of the present invention is to provide heat exchangers which overcome the problems and satisfy the requirements described above, while avoiding the deficiencies of prior devices. Another object of the invention is the provision of heat exchangers in which the above described by-passing or short circuiting of the fin spaces by the fluid flowing within the shell is substantially eliminated, and substantially all such fluid is constrained to flow between the fins on the finned tubes. A further object is to provide a heat exchanger of the type comprising a bundle of closely adjacent substantially parallel finned tubes disposed in an elongated shell of preferably circular cross section, in which the longitudinally extending recesses at the periphery of the bundle formed by the outer peripheries of adjacent finned tubes and the inner surface of the shell are closed by suitable closure means blocking the flow of fluid through said recesses. Another object is the provision of a heat exchanger of this type in which the longitudinally extending recesses within the bundle, defined by the circular peripheries of the outer edges of the fins, are closed by suitable closure means blocking the flow of fluid through such internal recesses and constraining it to flow between the fins of the tubes. A futrher object is to provide such a heat exchanger in which such closure means are made up of closure members each formed of substantially rigid sheet material and comprising a projecting portion having sur-

faces extending substantially the length of the finned tubes in close proximity to such tubes and having at least one end portion which blocks the flow of fluid through the recess and cause the fluid to flow between the fins of the fin tubes. A further object is the provision of such a heat exchanger in which the closure members are secured against longitudinal movement in the heat exchanger. Another object is to provide a heat exchanger in which the closure members may be readily installed, and removed to expose the finned tubes for inspection and cleaning. Another object is the provision of heat exchangers having these advantageous characteristics that can be manufactured readily and at a reasonable cost.

Further objects and advantages of the invention will become apparent from the following description of a preferred form thereof, reference being made to the accompanying drawings, in which;

FIGURE 1 is a longitudinal sectional view with parts broken away showing a preferred form of heat exchanger embodying the invention;

FIGURE 2 illustrates an end elevation of the heat exchanger, taken along line 2—2 of FIGURE 1;

FIGURE 3 is a sectional elevation, to a larger scale, along line 3—3 of FIGURE 1;

FIGURE 4 is a perspective elevation to an enlarged scale of a preferred form of a peripheral closure member for closing one of the peripheral recesses against the flow of fluid;

FIGURE 5 is a perspective elevation, to the same scale as FIGURE 4, of a preferred form of an internal closure member for closing one of the internal recesses against the flow of fluid;

FIGURE 6 shows end elevations of the closure members;

FIGURE 7 is a detail sectional elevation to an enlarged scale along line 7—7 of FIGURE 3, of a portion of the rear end of a shell section and the rear end of a peripheral closure member in place; and,

FIGURE 8 is a detail sectional elevation along the same section as FIGURE 7, of the front portion of a shell section showing the front ends of the peripheral and internal closure members in the heat exchanger of FIGURE 1.

The preferred form of heat exchanger embodying the invention and shown in the drawings comprises a pair of outer shell sections 10 and 11 disposed one above the other with their axes substantially parallel. These shell sections are connected together at their rear ends through a return section 12 secured by bolts 13 and nuts 14 to a flange 15 to which the rear ends of the shell sections 10 and 11 are fixed, as by welding; a sealing gasket 16 is preferably located between the flange 15 and the return section 12 to seal against the escape of fluid. The return section can thus be easily installed and removed; when it is removed the open rear ends of the shell sections permit access to the interior of the heat exchanger for inspection, cleaning or removal of interior parts.

The outer shell sections 10 and 11 may be supported by frame members 18 or any other suitable means. The forward ends of these outer shell sections are respectively provided with end or terminal members 19 and 20 to which conduit members 21 and 22 are secured, as will be explained in more detail below. A fluid or commodity is caused to flow through the outer tubes 10 and 11, being supplied and discharged through the laterally extending conduits 23 and 24 which communicate with the interior of shell sections 10 and 11 respectively near their forward ends. In the form of heat exchangers shown in the drawings, conduit 24 is the inlet and conduit 23 is the outlet, as indicated by the arrows; it will be understood, however, that the direction of flow of fluid through the outer shell sections may be reversed if desired.

In order to provide passages for another fluid or commodity to flow in heat exchange relation to the flow of fluid or commodity within the outer shell sections 10 and 11, a plurality of hairpin tubes 25 are disposed within the shell sections 10 and 11. Each inner tube 25 comprises two straight sections 26 provided with fins 27 on their external surfaces, and connected by welded return bends 28 disposed within the return section 12. The fins 27 are provided to increase the rate of heat exchange between the fluid or commodity within the inner or hairpin tubes 25 and the fluid or commodity surrounding these tubes and within the shell sections 10 and 11; the fins are preferably constructed according to the teachings of prior Patents Nos. 2,261,136 and 2,261,137. The fluid or commodity is supplied to the interior of the inner tubes 25 through connecting pipes 29 and 30 attached to conduit members 21 and 22; connecting pipe 29 constitutes the inlet and connecting pipe 30 constitutes the outlet, thus providing for counterflow of fluids or commodities in the heat exchanger shown in the drawings. Obviously, the flow can be reversed if desired; moreover it will be evident that the connecting pipes 29 and 30 and the laterally extending conduits 23 and 24 can be arranged to connect in series or in multiple a plurality of heat exchanger units.

At the front of the heat exchanger there are fluid tight connections that connect the interiors of connecting pipes 29 and 30 and the interiors of hairpin tubes 25, that seal the space outside the hairpin tubes 25 and inside the shell sections 10 and 11, that prevent leakage or intermingling of the fluids inside and outside of the hairpin tubes, and that permit the front end of the heat exchanger to be opened for inspection, cleaning or repair and for ease of assembly and disassembly of the exchanger. The connections illustrated in FIGURE 1 satisfy these requirements; for convenience that shown on the upper shell section 10 will be described, although both are identical. In this connection, the front ends of the hairpin tubes 25 are rigidly and tightly fixed in a tube sheet member 31 that has an external circular surface smaller than the smallest opening through the terminal member 19 and the shell section 10. The tube sheet member 31 is located against longitudinal inward movement by a split locking ring 33 fitting into an external groove on the member 31 and bearing against an outwardly facing shoulder 34 at the inner end of the counterbore 35 intermediate member 19; this counterbore is large enough to receive the locking ring. A sealing ring 36 located between members 31 and 19 and bearing against conduit member 21 to which pipe 29 is fixed, prevents leakage of the fluid in the space between the outside of the inner tube 25 and the inside of the shell section 10; a sealing ring 37 located between the ends of tube sheet member 31 and conduit member 21 seals against leakage of the fluid inside of the inner tubes 25. Studs 38 passing through conduit member 21 and threaded into terminal member 19, and nuts 39 on such studs serve to hold the connection together.

When it is decided to remove the inner tubes 25 for inspection, cleaning, repair or other purposes, the conduit members 21 and 22 and their associated seals at the front end of the exchanger are removed and the return section 12 at the rear of the exchanger is also removed. The hairpin tubes 25, together with the tube sheet member 31 in which their ends are secured, are moved forwardly until the split locking ring 33 clears the front end of member 19 and can be removed, and then are withdrawn rearwardly through the open rear ends of sections 10 and 11.

The illustrated heat exchanger has seven hairpin tubes 25. These tubes are arranged so their straight finned sections 26 form two bundles, one of which is shown in cross section in FIGURE 3. In each bundle the tubes are arranged so that one tube is at the center and the others surround it in close substantially parallel relation, all tubes in the bundle being preferably so arranged that their circular peripheries defined by the outer edges of the fins

27 on their straight sections 26 are in substantially tangential relation.

Preferably, as shown in FIGURE 3, the internal diameter of the shell section 10 or 11 associated with a bundle of finned tubes is such that its inner surface 42 closely approaches the outermost portion 43 of the periphery of each of the outer finned tubes of the bundle. Despite this, however, there are several peripheral recesses 44 of large cross section, each being formed by the outer adjacent portions of the finned peripheries of each pair of adjacent outer tubes in the bundle and by the adjacent portion of the inner surface of the shell surrounding the bundle. Each of these several recesses 44 extends throughout the finned length of the bundle. Moreover, within each bundle, there are several internal recesses 45 of large cross section, each being formed by the adjacent portions of the finned peripheries of tangentially related adjacent tubes. Each of these internal recesses 45 extends throughout the finned length of the bundle. Fluid flowing through these peripheral recesses 44 and internal recesses 45 can be heated only slightly if at all by the fluid flowing within the finned tubes, and yet a large proportion of the fluid flowing through the shell flows through such recesses in heat exchangers of conventional construction.

According to the present invention, however, the bypassing or short-circuiting of the fluid through these peripheral and internal recesses is eliminated, and substantially all of the fluid which would otherwise pass through such recesses, is constrained to flow in highly efficient heat transfer relation between the fins of the finned tubes in the bundle. In the illustrated embodiment this is accomplished by closure members 51 at the periphery which block the peripheral recesses 44, and by closure members 61 and 62 which block the internal recesses 45 of each bundle.

Each peripheral closure member 51, of which one is shown in perspective in FIGURE 4, is preferably formed of substantially rigid impervious material, such as sheet steel. It is substantially equal in length to the fins of the bundle; it has two parallel side edges 52 defining its width which is such that the edges of adjacent closure members 51 meet in substantially abutting relation at the outermost portions of the peripheries of adjacent finned tubes in the bundle, as shown in FIGURE 3. At least the end portion 54 nearest the end at which shell fluid enters the bundle, and preferably both end portions 53 and 54, of the closure member 51 are curved to closely approach or fit the inner surface of the shell section surrounding the bundle; the portion of the closure member 51 intermediate the end portions is formed with an inward projection 55 having two undersurfaces 56 which are preferably curved to closely approach or fit the outer periphery defined by the outer edges of the fins on adjacent finned tubes at the outer portion of the bundle, as shown in FIGURE 3, and which extend substantially throughout the length of the fins on such tubes. Since in the illustrated embodiment the inner surface of the shell section surrounding each bundle closely approaches the maximum cross sectional size of the bundle, the entire peripheral edge portion of each closure member 51, including its sides as well as its ends, closely approaches the inner surface of the shell, and the intermediate projecting portion of member 51 extends longitudinally into the associated recess 44 and closely approaches the edges of the fins defining the recess, as is preferable.

The assembled internal closure member 61 in the illustrated heat exchanger preferably takes the form of a cylindrical sleeve, made of substantially rigid impervious material such as sheet steel. It is preferably so shaped that its internal surface closely approaches or fits the outer edges of the fins 27 on the central finned tube 25, and its length substantially equals that of the fins.

In the illustrated heat exchanger there are several other internal closure members 62 which cooperate with closure member 61 to close the internal recesses 45. Each closure member 62, of which one is shown in perspective in FIGURE 5, also is preferably formed of substantially rigid impervious material such as sheet steel. Preferably it is as long as member 61, and hence substantially as long as the fins on the tubes with which it is associated, and has two parallel side edges 63, defining the width of the member, which is such that the edges of adjacent closure members 62 meet in substantially abutting relation at the innermost portions of the peripheries of adjacent finned tubes in the bundle. Preferably each such juncture between adjacent internal closure members 62 is located adjacent the outer surface of the central internal closure member 61 at the line of tangency, as shown in FIGURE 3. Each member 62 has at least the end portion 64 nearest the end at which the shell fluid enters the bundle, and preferably both end portions 64 and 65, curved to closely approach or fit the exterior surface of the central internal closure member 61; the portion of each closure member 62 intermediate its end portions is formed with an outward projection 66 having two outer surfaces 67 which are preferably curved to fit or closely approach the adjacent portions of the finned peripheries of adjacent tubes having their centers lying substantially on a common circle. As is apparent from FIGURES 1 and 3, the central internal closure member 61 and the surrounding internal closure members 62 combine to form means which blocks the short circuiting of any fluid through internal recesses 45 where it can bypass the fins, and thus diverts the fluid into the spaces between the fins of the finned tubes. The internal closure members 61 and 62 cooperate with the external or peripheral closure members 51 to constrain substantially all fluid passing through a shell section and outside of the finned tubes in a bundle, to flow through the spaces between the fins of such tubes in excellent heat transfer relationship to the fluid within such tubes. Preferably as shown in FIGURE 3, the peripheral and internal closure members when assembled in association with the bundle, form around the outer edges of each finned tube a substantially tubular channel of generally circular cross section extending substantially throughout the length of the fins.

The associated closure members fit together so closely that little if any fluid can leak into the peripheral recesses 44 or into the internal recesses 45, and any fluid which would get into such recesses would be prevented from flowing appreciably, if at all. The resulting stationary masses of fluid in the recesses would tend to act as heat insulators.

The closure members of the illustrated heat exchanger are firmly mounted, and held against longitudinal movement, by the straps 68 and 69 shown in FIGURES 1, 3, 5, and 6. The straps 68 are mounted on circular ends of the enclosure formed by the peripheral closure members 51, and the straps 69 are mounted on such enclosure at the intermediate portions. The straps are preferably formed of known steel strapping material applied by conventional methods and means with sufficient tension to firmly locate in place the central internal closure member 61, the surrounding internal closure members 62, and the external peripheral closure members 51; the members may thus be so firmly held that they cannot move longitudinally of the finned tubes even though subjected to substantial endwise force by the fluid in the shell sections. This secure mounting of the closure members is facilitated by their design which permits them to be compressed quite tightly by the bands without excessive pressure on, or intermeshing of, any fins of the tubes. The closure members cooperate with the fins and straps to provide a bundle which has greater strength and stiffness than the aggregate of the individual finned tubes, thus facilitating handling during assembly or disassembly of the heat exchanger, particularly if it is of considerable length.

The above described closure members in no way inter-

fere with the assembly of the heat exchanger or its disassembly for inspection, cleaning, repair or other purposes. In assembly, the closure members can easily be installed in and around each bundle of finned tubes of the unit made up of the group of hairpin tubes 25 and the tube sheet members 31 fixed at one end of the group of tubes before the unit is inserted into the shell sections. The central internal closure member 61 can easily be slid into place around the central finned tube, being preferably formed into longitudinal halves 70 and 71 to facilitate installation. The surrounding internal closure members 62 are then slid into the proper places between the tubes of the bundle, after which the external peripheral closure members 51 are inserted around the bundle. The straps 68 and 69 are then applied with sufficient tension to hold the closure members securely in place against transverse or longitudinal movement. The unit, with the closure members in place, can be easily installed by inserting it into the rear of the shell sections 10 and 11, and the assembly of the heat exchanger then completed. In disassembly, the unit made up of the group of hair-pin tubes and tube sheet members 31, with the closure members strapped in place on the bundles of finned tubes, is withdrawn from the rear ends on the shell section. If it is desired to expose the finned tubes, this can be easily accomplished by taking off the straps 68 and 69 and removing the closure members in the reverse of the assembly sequence described above. The fins of the finned tubes can thus be made completely accessible for inspection, cleaning, repair or other purposes indicated above as being highly desirable.

From the above, it is apparent that we have overcome the deficiencies of prior heat exchangers embodying bundles of finned tubes having peripheral and internal recesses through which fluid by-passes or short-circuits the fins, by providing heat exchangers embodying closure means which block such peripheral and internal recesses and constrain the fluid which would ordinarily pass through such recesses to flow between the fins in efficient heat exchange relation, thus solving the problems and overcoming the disadvantages described above. Exceptional benefits are provided in the cooling or heating of viscous liquids which are thus prevented from flowing through the peripheral and internal recesses where flow resistance and heat transfer effectiveness are less, but are caused to flow substantially entirely through the spaces between the fins where heat transfer effectiveness is greatest. The magnitude of these benefits and the great increase in heat exchange efficiency provided by this invention are apparent from the fact that in a heat exchanger having the cross sectional proportions of the illustrated embodiment the peripheral and internal recesses which are thus blocked against fluid flow in each shell section have a total cross sectional area which is about 75% as great as the total cross sectional area available for fluid flow between the fins of the finned tubes of the bundle in the shell section. Furthermore, advantages of the invention can be obtained without impairing the assembly or disassembly of the heat exchanger which is extremely desirable for inspection, cleaning, or repair. Notwithstanding these important advantages, heat exchangers embodying the advantages of the invention can be made with very little, if any, added cost over prior heat exchangers.

While in each of the embodiments described above, seven finned tubes are employed in each bundle, it is obvious that bundles having more or less finned tubes may be employed, and the invention may be applied to heat exchangers of different types than that specifically described in the illustrated embodiments. The means closing the internal and peripheral recesses may also differ from those specifically shown. These and other modifications of the invention will be apparent to those skilled in the art. It is therefore to be understood that the patent is not limited to the preferred form of invention disclosed herein or in any other manner than by the scope of the appended claims.

We claim:

1. A heat exchanger comprising

a bundle of elongated finned heat exchange tubes, each of which has thereon a plurality of longitudinally extending external fins the outer edges of which define a periphery of generally circular cross section, said tubes being positioned in said bundle so that the generally circular peripheries defined by the fins of adjacent outer tubes in the bundle are in substantially tangential, close, substantially parallel relationship, and outer edges of fins of said tubes define the periphery of the bundle and cause it to have circumferentially spaced substantially parallel valleys extending longitudinally of said bundle;

means for passing fluid longitudinally inside said finned tubes;

an elongated shell surrounding said bundle of finned tubes and having an inner surface of a cross section such that it encircles only the outer edges of the outermost fins of said outer tubes and is separated from said outermost fin edges by substantially only a distance sufficient to permit the tube bundle to be inserted into said shell,

there being a plurality of circumferentially spaced substantially parallel recesses between the periphery of said bundle and said shell, each of said peripheral recesses being formed by one of said valleys at the periphery of the bundle and by the portion of the inner surface of the shell extending over said valley into close proximity to the outermost fin edges of the adjacent outer finned tubes defining the valley;

means for passing fluid longitudinally through said shell outside of said finned tubes; and

a plurality of juxtaposed elongated closure members, each formed of substantially rigid material, which block flow of fluid through said peripheral recesses and constrain substantially all fluid flowing through the shell to flow within said bundle periphery defined by outer edges of fins of said outer tubes in said bundle, said closure members being shaped so that when juxtaposed they form a substantially fluid impervious enclosure

which surrounds said bundle of tubes and extends substantially throughout the length of the fins thereon,

which has portions extending into said peripheral recesses and having surfaces which substantially engage the outer edges of substantially all of the fins defining said recesses, and

which has a barrier portion providing a surface substantially engaging the inner surface of said shell substantially entirely around the inner surface of said shell to prevent fluid flow between said enclosure and said shell.

2. A heat exchanger comprising

a bundle of elongated finned heat exchange tubes, each of which has thereon a plurality of longitudinally extending external fins the outer edges of which define a periphery of generally circular cross section, said tubes being positioned in said bundle so that the generally circular peripheries defined by the fins of adjacent outer tubes in the bundle are in substantially tangential, close, substantially parallel relationship, and outer edges of fins of said tubes define the periphery of said bundle and cause it to have circumferentially spaced substantially parallel valleys extending longitudinally of said bundle, all of said valleys having substantially identical cross sections;

means for passing fluid longitudinally inside said finned tubes;

an elongated shell surrounding said bundle of finned tubes and having an inner surface of a cross section such that it encircles only the outer edges of the outermost fins of said outer tubes,

there being a plurality of circumferentially spaced substantially identical and substantially parallel recesses between the periphery of said bundle and said shell, each of said peripheral recesses being formed by one of said valleys at the periphery of the bundle and by the portion of the inner surface of the shell extending over said valley into proximity to the outermost fin edges of the adjacent outer finned tubes defining the valley;

means for passing fluid longitudinally through said shell outside of said finned tubes;

and a plurality of juxtaposed elongated closure members which block flow of fluid through said peripheral recesses and constrain substantially all fluid flowing through said shell to flow within said bundle periphery defined by outer edges of fins of outer tubes in said bundle, each of said closure members

being formed of substantially rigid material and extending substantially throughout the length of the fins on said tubes,

having longitudinal side edges each of which substantially engages the side edge of an adjacent juxtaposed closure member,

having a laterally projecting portion providing surfaces which extend throughout the length and substantially engage the outer edges of substantially all of the fins defining at least one of said recesses,

and having a portion which substantially engages the inner surface of said shell to form with like portions of juxtaposed closure members a barrier extending substantially entirely around the inner surface of said shell and substantially preventing fluid flow between said closure member and the shell.

3. A heat exchanger comprising

a bundle of elongated finned heat exchange tubes, each of which has thereon a plurality of longitudinally extending external fins the outer edges of which define a periphery of generally circular cross section,

said tubes being positioned in said bundle so that the generally circular peripheries defined by the fins of adjacent outer tubes in the bundle are in substantially tangential, close, substantially parallel relationship, and other edges of fins of said tubes define the periphery of said bundle and cause it to have circumferentially spaced substantially parallel valleys extending longitudinally of said bundle;

means for passing fluid longitudinally inside said finned tubes;

an elongated shell surrounding said bundle of finned tubes and having an inner surface of a cross section such that it encircles only the outer edges of the outermost fins of said outer tubes and is separated from said outermost fin edges by substantially only a distance sufficient to permit the tube bundle to be inserted into said shell,

there being a plurality of circumferentially spaced substantially parallel recesses between the periphery of said bundle and said shell, each of said peripheral recesses being formed by one of said valleys at the periphery of the bundle and by the portion of the inner surface of the shell extending over said valley into close proximity to the outermost fin edges of the adjacent outer finned tubes defining the valley;

means for passing fluid longitudinally through said shell outside of said finned tubes;

and a plurality of juxtaposed elongated closure members which block flow of fluid through said peripheral recesses and constrain substantially all fluid flowing through said shell to flow within the bundle periphery defined by outer edges of fins of said outer tubes in said bundle, each of said closure members

being formed of substantially rigid sheet material and extending substantially throughout the length of the fins on said tubes,

having longitudinal side edge portions which substantially engage the outermost fin edges of adjacent outer finned tubes and also the inner surface of said shell and which substantially abut the side edge portions of adjacent closure members,

having a laterally projecting portion substantially engaging the outer edges of substantially all of the fins defining the peripheral recess between said outermost fin edges of adjacent outer finned tubes engaged by said side edge portions, and

having at least one integral barrier portion which cooperates with like barrier portions of other closure members to form a substantially fluid tight barrier extending from said laterally projecting portions of said closure members substantially to and entirely around the inner surface of said shell.

4. A heat exchanger comprising

a bundle of elongated finned heat exchange tubes, each of which has thereon a plurality of longitudinally extending external fins the outer edges of which define a periphery of generally circular cross section,

said tubes being positioned in said bundle so that the generally circular peripheries defined by the fins of adjacent outer tubes in the bundle are in substantially tangential, close, substantially parallel relationship, and outer edges of fins of said tubes define the periphery of the bundle and cause it to have circumferentially spaced substantially parallel valleys extending longitudinally of said bundle;

means for passing fluid longitudinally inside of said finned tubes;

an elongated shell surrounding said bundle of finned tubes and having an inner surface of a cross section such that it encircles only the outer edges of the outermost fins of said outer tubes and is separated from said outermost fin edges by substantially only a distance sufficient to permit the tube bundle to be inserted into said shell,

there being a plurality of circumferentially spaced substantially parallel recesses between the periphery of said bundle and said shell, each of said peripheral recesses being formed by one of said valleys at the periphery of the bundle and by the portion of the inner surface of the shell extending over said valley into close proximity to the outermost fin edges of the adjacent outer finned tubes defining the valley;

means for passing fluid longitudinally through said shell outside of said finned tubes;

and a plurality of juxtaposed substantially identical elongated closure members arranged in edge-abutting relationship around said tube bundle, which block flow of fluid through said peripheral recesses and constrain substantially all fluid flowing through the shell to flow within said bundle periphery defined by outer edges of fins of said outer tubes in said bundle, each of said closure members being formed of substantially rigid sheet material and

having a central portion which projects laterally inwardly into one of said peripheral recesses and extending throughout the major portion of the length of said recess, said central portion being so shaped as to engage the outer edges of substantially all of the fins defining said re-

cess, the surface of said closure member outside said central portion comprising a marginal portion extending entirely around the periphery of said closure member and substantially engaging the inner surface of said shell.

5. A heat exchanger comprising

a bundle of elongated finned heat exchange tubes, each of which has thereon a plurality of longitudinally extending external fins the outer edges of which define a periphery of generally circular cross section,

said tubes being positioned in said bundle so that the generally circular peripheries defined by the fins of adjacent tubes in the bundle are in substantially tangential, close, substantially parallel relationship, outer edges of fins of adjacent outer tubes in the bundle defining the periphery of said bundle and causing it to have circumferentially spaced substantially parallel valleys extending longitudinally of the exterior of said bundle, and outer edges of fins of adjacent finned tubes also defining recesses extending internally longitudinally of said bundle;

means for passing fluid longitudinally inside of said finned tubes;

an elongated shell surrounding said bundle of finned tubes and having an inner surface of a cross section such that it encircles only the outer edges of the outermost fins of said outer tubes and is separated from said outermost fin edges by substantially only a distance sufficient to permit the bundle to be inserted into said shell,

there being a plurality of circumferentially spaced substantially parallel recesses between the periphery of said bundle and said shell, each of said peripheral recesses being formed by one of said valleys at the periphery of the bundle and by the portion of the inner surface of the shell extending over said valley into close proximity to the outermost fin edges of the adjacent outer finned tubes defining the valley;

means for passing fluid longitudinally through said shell outside of said finned tubes;

a plurality of juxtaposed elongated closure members, each formed of substantially rigid material, which block flow of fluid through said peripheral recesses and constrain substantially all fluid flowing through the shell to flow within said bundle periphery defined by outer edges of fins of said outer tubes in said bundle, said closure members being shaped so that when juxtaposed they form a substantially fluid impervious enclosure

which surrounds said bundle of tubes and extends substantially throughout the length of the fins thereon,

which has portions extending into said peripheral recesses and having surfaces which substantially engage the outer edges of substantially all of the fins defining said recesses, and

which has a barrier portion providing a surface substantially engaging the inner surface of said shell substantially entirely around the inner surface of said shell to prevent fluid flow between said enclosure and said shell; and

closure means which substantially blocks flow of fluid through each of said internal recesses, having surfaces extending substantially throughout the length and substantially engaging the outer edges of substantially all of the fins defining each of said recesses.

6. A heat exchanger comprising

a bundle of elongated finned heat exchange tubes, each of which has thereon a plurality of longitudinally extending external fins the outer edges of which define a periphery of generally circular cross section,

said tubes being positioned in said bundle so that the generally circular peripheries defined by the fins of adjacent outer tubes in the bundle are in substantially tangential, close, substantially parallel relationship, outer edges of fins of adjacent outer tubes in the bundle defining the periphery of said bundle and causing it to have circumferentially substantially parallel valleys extending longitudinally of the exterior of said bundle, and outer edges of fins of adjacent finned tubes also defining recesses extending internally longitudinally of said bundle;

means for passing fluid longitudinally inside of said finned tubes;

an elongated shell surrounding said bundle of finned tubes and having an inner surface of a cross section such that it encircles only the outer edges of the outermost fins of said outer tubes and is separated from said outermost fin edges by substantially only a distance sufficient to permit the tube bundle to be inserted into said shell,

there being a plurality of circumferentially spaced substantially parallel recesses between the periphery of said bundle and said shell, each of said peripheral recesses being formed by one of said valleys at the periphery of the bundle and by the portion of the inner surface of the shell extending over said valley into close proximity to the outermost fin edges of the adjacent finned tubes defining the valley;

means for passing fluid longitudinally through said shell outside of said finned tubes; and

means substantially closing against flow of fluid said peripheral recesses between the bundle and shell, and said internal recesses within said bundle, said means forming around the outer edges of the fins of each finned tube in the bundle a tubular channel of generally circular cross section which extends substantially throughout the length of the fins, and said means causing substantially all fluid flowing through said shell to flow between the fins of the tubes of said bundle.

7. A heat exchanger comprising

a bundle of elongated finned heat exchange tubes, each of which has thereon a plurality of longitudinally extending external fins the outer edges of which define a periphery of generally circular cross section,

said tubes being positioned in said bundle so that the generally circular peripheries defined by the fins of adjacent outer tubes in the bundle are in substantially tangential, close, substantially parallel relationship, outer edges of fins of adjacent outer tubes in the bundle defining the periphery of said bundle and causing it to have circumferentially spaced substantially parallel valleys extending longitudinally of the exterior of said bundle, and outer edges of adjacent finned tubes also defining recesses extending internally longitudinally of said bundle;

means for passing fluid longitudinally inside of said finned tubes;

an elongated shell surrounding said bundle of finned tubes and having an inner surface of a cross section such that it encircles only the outer edges of the outermost fins of said outer tubes and is separated from said outermost fin edges by substantially only a distance sufficient to permit the tube bundle to be inserted into said shell,

there being a plurality of circumferentially spaced substantially parallel recesses between the periphery of said bundle and said shell, each of said peripheral recesses being formed by one of said valleys at the periphery of the bundle and by the portion of the inner surface of the shell extending over said valley into close prox-

imity to the outermost fin edges of the adjacent finned tubes defining the valley;

means for passing fluid longitudinally through said shell outside of said finned tubes;

means substantially closing said peripheral recesses against flow of fluid and constraining substantially all fluid flowing through said shell to flow within the bundle periphery defined by the fins of said outer tubes in said bundle; and

a plurality of juxtaposed elongated closure members, which block flow of fluid through said internal recesses, each of said closure members being formed of substantially rigid material,

having side edges which substantially engage the outer edges of fins of finned tubes defining at least one internal recess, and each of which side edges substantially engages the side edge of an adjacent closure member,

having at least one portion substantially engaging the outer edges of substantially all of the fins defining at least one internal recess substantially throughout the length of said fins, and

having an integral portion which forms a barrier substantially blocking flow of fluid through said internal recess.

8. A heat exchanger comprising

a bundle of elongated finned heat exchange tubes, each of which has thereon a plurality of longitudinally extending external fins the outer edges of which define a periphery of generally circular cross section,

said tubes being positioned in said bundle so that one of them is located at the center of the bundle and outer tubes surround it with their generally circular peripheries in substantially tangential, close, substantially parallel relation to adjacent outer tubes and to said central tube, outer edges of fins of adjacent outer tubes in the bundle defining the periphery of said bundle and causing it to have circumferentially spaced substantially identical, substantially parallel valleys extending longitudinally of the exterior of said bundle, and outer edges of fins of adjacent finned tubes also defining substantially identical, substantially parallel recesses extending internally longitudinally of said bundle between said central finned tube and said outer finned tubes;

means for passing fluid longitudinally inside of said finned tubes;

an elongated shell surrounding said bundle of finned tubes and having an inner surface of a cross section such that it encircles only the outer edges of the outermost fins of said outer tubes,

there being a plurality of circumferentially spaced substantially parallel recesses between the periphery of said bundle and said shell, each of said peripheral recesses being formed by one of said valleys at the periphery of the bundle and by the portion of the inner surface of the shell extending over said valley into proximity to the outermost fin edges of the adjacent finned tubes defining the valley;

means for passing fluid longitudinally through the shell outside of said finned tubes;

means substantially closing said peripheral recesses against flow of fluid and constraining substantially all fluid flowing through said shell to flow within said bundle periphery defined by fins of the outer tubes in said bundle; and

means substantially closing said internal recesses against flow of fluid and constraining substantially all fluid flowing through said shell within said bundle periphery to flow within the peripheries defined by the outer edges of the fins on said finned tubes, said means being formed by a plurality of juxtaposed elongated closure members which when assembled define a substantially cylindrical, substantially fluid tight surface which substantially engages the outer edges of the fins of said central tube substantially throughout the length of said fins,

also define a substantially fluid tight surface which extends substantially throughout the length and substantially engages the outer edges of substantially all of the fins of said outer tubes defining said internal recesses, and

also define surfaces extending between said last named surface and said substantially cylindrical surface and substantially blocking flow of fluid through said internal recesses.

9. A heat exchanger comprising

a bundle of elongated finned heat exchange tubes, each of which has thereon a plurality of longitudinally extending external fins the outer edges of which define a periphery of generally circular cross section,

said tubes being positioned in said bundle so that one of them is located at the center of the bundle and outer tubes surround it with their generally circular peripheries in substantially tangential, close, substantially parallel relation to adjacent outer tubes and to said central tube, outer edges of fins of adjacent outer tubes in the bundle defining the periphery of said bundle and causing it to have circumferentially spaced substantially parallel valleys extending longitudinally of the exterior of said bundle, and outer edges of fins of adjacent finned tubes also defining recesses extending internally longitudinally of said bundle between said central finned tube and said outer finned tubes;

means for passing fluid longitudinally inside of said finned tubes;

an elongated shell surrounding said bundle of finned tubes and having an inner surface of a cross section such that it encircles only the outer edges of the outermost fins of said outer tubes and is separated from said outermost fin edges by substantially only a distance sufficient to permit the bundle to be inserted into said shell;

there being a plurality of circumferentially spaced substantially parallel recesses between the periphery of said bundle and said shell, each of said peripheral recesses being formed by one of said valleys at the periphery of the bundle and by the portion of the inner surface of the shell extending over said valley into close proximity to the outermost fin edges of the adjacent outer finned tubes defining the valley;

means for passing fluid longitudinally through the shell outside of said finned tubes;

means substantially closing said peripheral recesses against flow of fluid and constraining substantially all fluid flowing through said shell to flow within said bundle periphery defined by outer edges of fins of the outer tubes in said bundle; and

means substantially closing said internal recesses against flow of fluid and constraining substantially all fluid flowing through said shell within said bundle periphery to flow within the peripheries defined by the outer edges of the fins on said finned tubes, said means comprising

tubular housing means formed of substantially rigid sheet material surrounding and substantially engaging

substantially throughout their lengths the outer edges of the fins of said central tube,

and a plurality of juxtaposed elongated closure members formed of substantially rigid sheet material, each of said members having

longitudinal side edges which abut the longitudinal side edges of adjacent closure members and contact said tubular housing at the locations

where the peripheries defined by the outer edges of fins of a pair of adjacent outer tubes are in substantially tangential relations to said central tube,

end edges which substantially engage the end portions of said tubular housing, and

an intermediate portion which extends from said side and end edges into the internal recess formed by said pair of adjacent outer tubes and substantially engages the outer edges of substantially all of the fins of said outer tubes forming said internal recess.

10. The heat exchanger of claim 1 in which said closure members are secured in place on said bundle by encircling strapping means.

11. The heat exchanger of claim 4 in which said closure members are secured in place on said bundle by encircling strapping means.

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