June 15, 1948. W. BISCH 2,443,295

METHOD OF MAKING HEAT EXCHANGERS

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FIG. 1

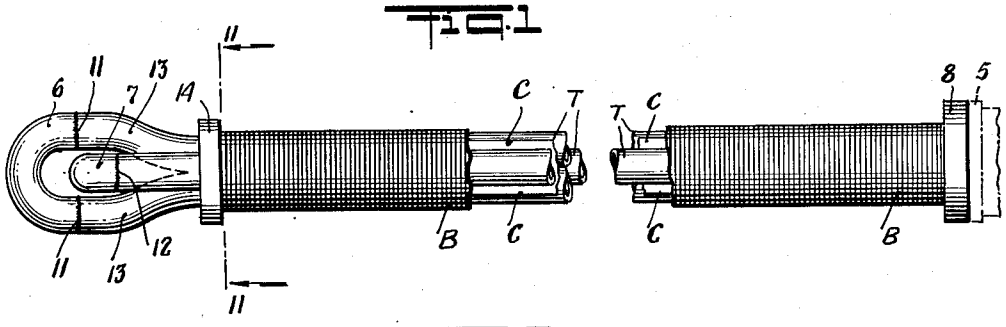


FIG. 2

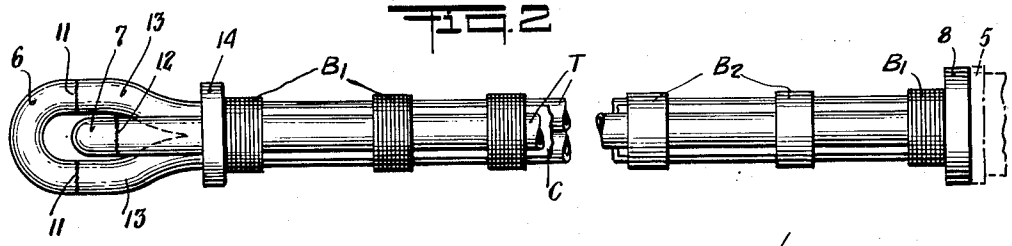


FIG. 3

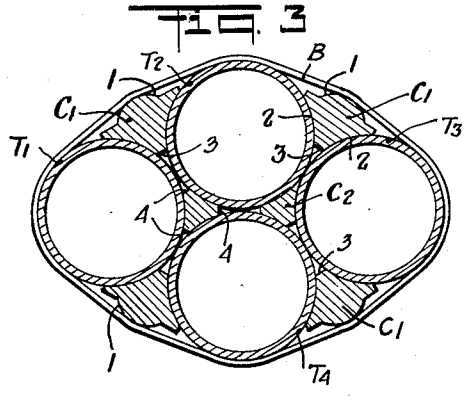


FIG. 4

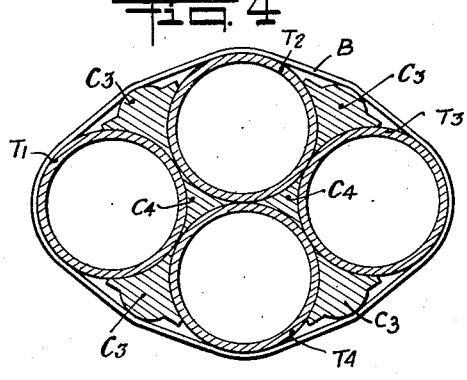


FIG. 5

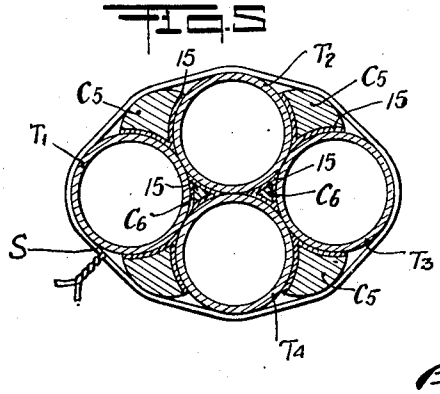
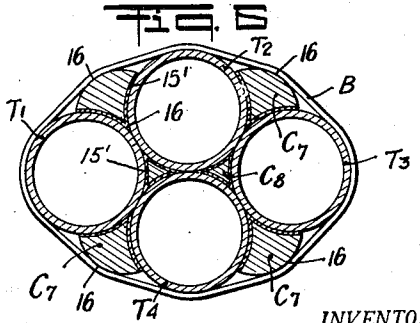


FIG. 6



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Fig. 7

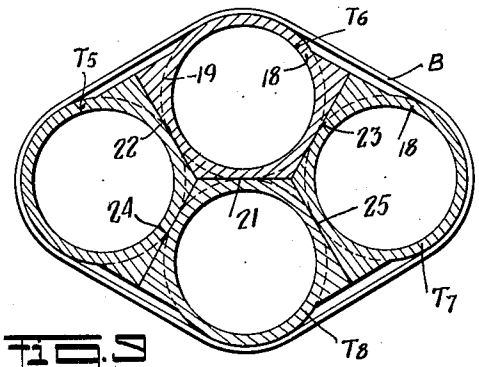


Fig. 8

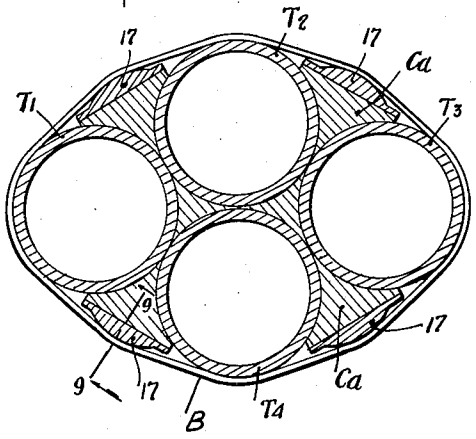


Fig. 9

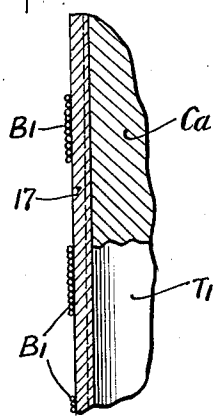


Fig. 10

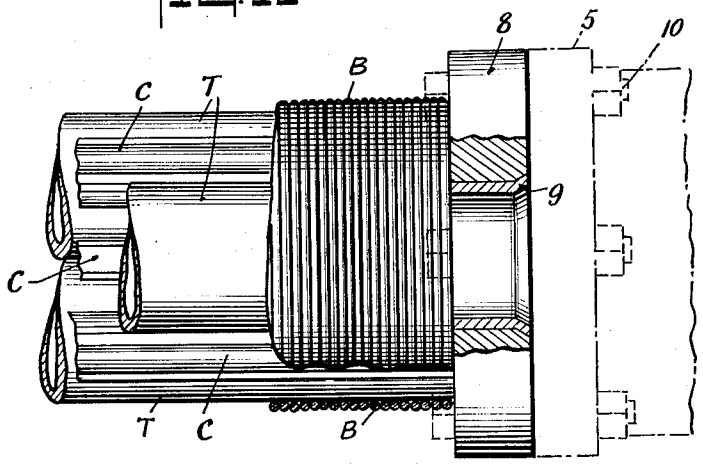


Fig. 11

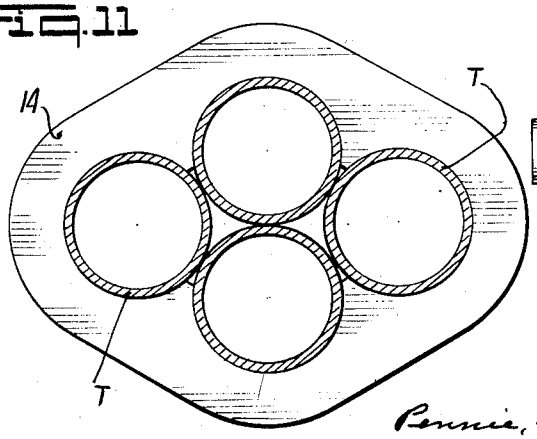
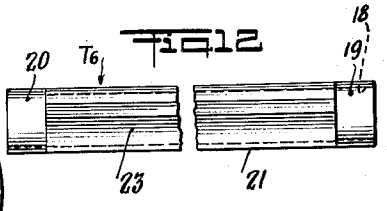


Fig. 12



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UNITED STATES PATENT OFFICE

2,443,295

METHOD OF MAKING HEAT EXCHANGERS

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Application May 19, 1944, Serial No. 536,250

4 Claims. (Cl. 29—157.3)

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This invention relates to heat exchange apparatus and, more particularly, to an improved and simplified construction of heat exchanger.

In numerous industrial operations it is desirable or essential that heat be economically transferred from a comparatively hot fluid to a fluid of lower temperature. Thus, for example, in an oil refinery the efficient operation of the plant often depends upon the completeness with which the heat content of different fluids is interchanged at different stages of their flow. Not infrequently the temperatures of both the hot fluid and the cooler fluid are not only comparatively high but also a comparatively large temperature difference exists between them. The mechanical construction of the heat exchanging device employed under such conditions and for such purpose is an important item, since this construction determines the thermal efficiency and economy of operation as well as the adaptability of the device to various installations.

In general, an economical heat exchanging device should provide the maximum thermal efficiency consistent with a reasonable initial cost and maintenance cost and should be constructed to operate without disability by reason of the different degrees of expansion which take place under widely differing temperatures in closely adjacent parts. The device should provide for easy cleaning of the fluid passages and fluid-tight joints between its component parts. In certain processes it is desirable or essential that one or both of the fluids between which an exchange of heat is desired be delivered not only at comparatively high temperature but also at comparatively high pressure, and accordingly the heat exchanging device should be capable of withstanding high pressures at high temperatures without danger of leakage or rupture.

In accordance with the present invention there is provided an improved heat exchanger for effecting the efficient transfer of heat between various kinds of fluids at extremely high pressures.

A further object of the invention is the provision of a device of the type described which, although of simple and comparatively inexpensive construction, is capable of handling fluids under very high pressures and temperatures without danger of leakage or rupture.

In United States Patent 2,013,187 issued September 3, 1935, to Joseph Price and assigned to the same assignee as the present application, there is described and claimed a heat exchange device of the type in question which is formed by using comparatively thin metal tubes of steel

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or other suitable material and by passing such tubes through openings in a plurality of metal plates, the plates being spaced closely and uniformly along the tubes. The tubes are then expanded into intimate and rigid heat exchanging contact with the plates by drawing expanding elements through the tubes.

While heat exchangers of such construction have reached a high degree of commercial success, large quantities of them having been manufactured and being now in use, nevertheless the construction possesses limitations. For example, the metal plates or fins connecting the tubes must have sufficient strength to withstand the expansion process. Consequently a ferrous metal is ordinarily used for these plates and this metal interposes a rather high resistance to the heat transfer. Moreover, in order for the fins to have sufficient strength it is necessary for the tubes to be spaced not less than about ¼ inch apart and excess metal is required at the ends and sides of the fins; the weight of the fins consequently is a considerable factor and tends to make the heat exchanger heavy. Furthermore, this construction is limited as to the permissible temperature difference between the tubes because of the expansion strains set up in the plates which are locked securely to the tubes by the expanding process. Finally, the center-to-center distance between the tubes is fixed by the expanding machine and prohibits the use of a larger and a smaller tube or tubes in the same unit without increasing the resistance to heat flow between the tubes.

The present invention aims, more specifically, to overcome these difficulties and to provide a tube-to-tube heat exchanger adapted for use at high pressures and temperatures having a greatly reduced resistance to heat transfer and which is lighter in weight, more compact, easy to clean and tends to keep itself clean.

Another object of the invention is to provide a heat exchanger of the type described in which excessive stresses of expansion are eliminated even when there is a very large difference in temperature between the comparatively hot fluid and the cooler fluid.

A further object of the invention is to provide a heat exchanger of the type described in which tubes of different size may be employed without reducing the efficiency of heat transfer, and thereby enabling the proper velocity ratio between the two fluids to be maintained.

A still further object of the invention is the provision of an improved method of construct-

ing heat exchanging devices of the type described.

The invention will be understood from a consideration of the accompanying drawings and of the appended claims, certain modifications of the invention being illustrated for the purpose of exemplifying the means of carrying out the invention. In these drawings:

Fig. 1 is a side view of a heat exchanger unit constructed according to the invention;

Fig. 2 is a similar view of a modified form of heat exchanger unit;

Fig. 3 is a cross sectional view of the assembled parts of a heat exchanger element;

Fig. 4 is a view similar to Fig. 3 showing the parts after the completion of a preferred additional step in the manufacture of the device;

Figs. 5 and 6 are views showing steps in the manufacture of the preferred embodiment of the invention;

Fig. 7 is a cross sectional view of a modification;

Fig. 8 is a cross sectional view of another modification;

Fig. 9 is a fragmentary longitudinal section taken on line 9—9 of Fig. 8;

Fig. 10 is an enlarged view, partly in elevation and partly in section, of the right hand end of the device shown in Fig. 1;

Fig. 11 is a cross sectional view taken on line 11—11 of Fig. 1; and

Fig. 12 is a view in side elevation and drawn to a reduced scale of one of the elements of the device shown in Fig. 7.

Referring to the drawings, the heat exchanger unit of the invention comprises generally a plurality of tubes or pipes T arranged side by side, or nested, against one another in parallel relation leaving spaces or pockets between them extending lengthwise substantially from end to end of the unit, and in these pockets are elongated strips or bars forming cores C of good heat conducting material, both the tubes and cores being bound together by means of a binding B extending substantially throughout the length of the device to maintain heat transfer contact between the tubes and cores. The binding permits the tubes to slide one with respect to another when one tube is hotter than another, and thus to prevent high expansion stresses from being set up in the device. Certain of the tubes T, usually two or more, are arranged for carrying a comparatively hot fluid, while another tube, or tubes, of the group carries a comparatively cool fluid, and the elongated strips, or bars, of heat-conducting material forming the cores serve as a heat transferring medium for efficiently carrying heat from the hot tubes to the cooler tubes.

In the construction of the disclosed embodiment of the invention, each unit of the heat exchanger shown comprises four tubes T_1, T_2, T_3 and T_4. These tubes are preferably comparatively thin walled and may conveniently comprise seamless drawn tubes of steel or other suitable metal. The elongated strips or bars which form the cores may take various shapes, and as shown in Fig. 3, may comprise four outer core strips C_1 within the lengthwise pockets between the tubes, and two inner core strips C_2 of smaller cross sectional area within the internal spaces or pockets. This results in two of the tubes—for example tubes T_2 and T_4, being in contact with one another, and the other two tubes T_1 and T_3 being spaced apart from each other but in contact with each of the other tubes T_2 and T_4.

Also the resulting cross section of the device is that of an oblique parallelogram with rounded corners, the sides of the parallelogram preferably being not quite straight because the outer central portions of the core strips C_1 should bulge outwardly as by the presence of ribs or protuberances 1 extending lengthwise, in order that the binding B may under all conditions urge the core strips against the surfaces of the tubes.

The outer core strips C_1 are formed with curved inner surfaces 2 which conform to the curvature of the tube surfaces. The apex 3 which is formed at the intersection between these curved surfaces 2 is preferably flattened as shown in Fig. 3 to facilitate manufacture of the core strips and their assembly with the tubes. The inner core strips C_2 are of generally triangular cross section, their three substantially equal sides, however, having the same curvature as the tube surfaces instead of being straight. The apexes 4 are blunted or flattened in a similar manner to the apex 3 of core strips C_1.

The binding B may consist of a continuous wire closely wrapped or wound about the heat exchanger from end to end as shown in Fig. 1. This wire should have suitable tensile strength and toughness, such as bridge wire or piano wire. Instead of employing a continuous binding such as shown in Fig. 1, short spaced sections such as shown at B_1 in Fig. 2 of closely wound wire may be employed. Also metal clamping bands B_2, as shown in Fig. 2, may be used, the ends of which may be welded together or secured in any suitable manner.

As shown in Fig. 3, small air spaces exist between the apexes 3 of the outer core C_1 and the apexes 4 of the inner cores C_2. It is desirable to eliminate these air spaces and provide a continuous metallic path for the flow of heat between the tubes. Preferably, therefore, the cores C_1 and C_2 are constructed of a metal which will flow under the application of pressure or heat, or both, such for example, as copper, aluminum, or a suitable alloy. In Fig. 4 the metal of cores C_1 and C_2 has been made to flow so that the apexes 3 of cores C_1 have moved inwardly and the apexes 4 of cores C_2 have also been extended, thus completely eliminating the air spaces shown in Fig. 3 and forming cores having outer and inner portions C_3 and C_4 and completely filling the five elongated spaces between the four tubes extending from end to end of the heat exchanger.

It is generally prefered to employ each unit of the heat exchanger as a double pass heat exchange device, although this arrangement is not essential to the invention. Thus in the disclosed embodiment means are provided for passing a comparatively hot fluid through the tubes T_2 and T_4 of the unit and for passing a comparatively cool fluid through the tubes T_1 and T_3 thereof. The comparatively hot and cool fluids may be conducted through the tubes by the use of a stationary head 5 (Figs. 1, 2 and 10) at one end of each unit, and by return connections 6 and 7 at the opposite end. In order to make the connections with head 5 the unit is provided with an end flange 8. The ends of the tubes may be expanded into flange 8, as indicated at 9 in Fig. 10 and the flanges secured to head 5 by means of a series of bolts 10.

At the opposite end of the heat exchanging device the return connections 6 and 7 may conveniently comprise return bends formed of the same material as the tubes T and welded to these tubes

as indicated at 11 and 12, respectively. To accommodate these connections the outer ends 13 of tubes T_2 and T_4, respectively, are offset so that the outer return bend 6 encompasses the inner return bend 7. To facilitate the offsetting of tubes T_2 and T_4 a strengthening fin or flange 14 is provided to surround the heat exchanger tubes as shown in Figs. 11, 1 and 2. Fin 14 is of sufficient strength to withstand the bending stresses accompanying the formation of the offset portions in the ends 13.

In the heat exchanger unit as thus constructed, the flow path for each of the fluids has substantially uniform area from ingress to egress, tending to keep the unit clean, that is, free of scale or deposit from the fluid passing through it. Also in case such deposit does accumulate through extended use the flow passages are not difficult to clean.

It will be understood that head 5 contains ingress and egress channels (not shown) for conveying the respective fluids to and from the two pairs of tubes. Thus the comparatively hot fluid may flow into the end of tubes T_2 from head 5, then through the tube to the return bend 6 and thence through tube T_4 back to head 5 where it enters an egress channel therein. Also the comparatively cool fluid may enter tube T_1 from a separate inflow channel in head 5 and thence flow through tube T_1, return bend 7 and tube T_3 where it enters a fourth channel in head 5. The heads 5 may be constructed, for example, as shown in the previously mentioned U. S. patent, and any desired number of the heat exchanger units may be assembled to form a unitary heat exchange device of any desired capacity as disclosed in that patent. Thus a plurality of such units may be assembled in series relation by employing heads as disclosed in that patent. It will be understood that the heat exchanger units of the present invention may be constructed of tubes T of any desired length to suit a particular installation. Also as disclosed in that patent, the heat exchange units can be made in sections where it is desirable to employ a unit of extreme length.

Although in the described embodiments two tubes are provided for hot fluids and two for cooler fluids, the number of tubes employed for each fluid may be varied as desired, and the invention is not limited to the number of cool and hot tubes shown. Thus the units may be of the single pass type with one or more tubes for each fluid and no return flow. When a plurality of passes is to be employed, two or more tubes are used for the hot fluid and two or more tubes for the cooler fluid. Different numbers of tubes may be used for the different fluids. For example, the unit may comprise three tubes for carrying one fluid and six tubes for carrying the other.

Also, the tube, or tubes, for carrying the hot fluid may be of different size from the tube, or tubes, for carrying the cooler fluid. In this way the fluids may be caused to flow at different velocities to establish the maximum rate of heat transfer between the two fluids for any particular installation. When either pair of tubes, for example, tubes T_1 and T_3 is made smaller in diameter than the other pair T_2 and T_4, the cross section of the elongated outer and inner core strips may be modified correspondingly but the length of the path of heat conduction from tube to tube through the cores is not increased. Consequently there is no change in the rate of heat transfer due to an increase in length of the path of heat conduction from one tube to another.

Should it be found desirable to do so, the diameter of one of the four tubes or of one of each pair of the tubes may be reduced or increased as required to produce the desired fluid velocity in that particular tube.

Referring now to the modification of Figs. 5 and 6, instead of providing elongated core strips of metal which can be made to flow under the application of heat or pressure, or both, the elongated core strips C_5 and C_6 of suitable metal of good heat conductivity are provided with a coating 15 (exaggerated somewhat in the drawings) and consisting of a metal which will readily flow under the application of heat or pressure, or both. Thus the cores C_5 and C_6 may be made of copper or aluminum, or the like, which has been coated in any suitable manner with a layer 15 of a soft metal such as solder which will flow when subjected to a suitable pressure or temperature, or both. Layer 15 should be applied to all three sides of inner cores C_6, whereas it may be applied to the two inner sides only of the outer cores C_5. The tubes and core strips may be assembled as shown in Fig. 5 and held together temporarily by wire strands S placed at intervals along the assembly, and then subjected to a suitable temperature and the binding B applied causing the layer of soft metal 15 to flow into and fill the lengthwise small spaces between the tubes and cores, as shown in Fig. 6. The layer or coating 15, at least on the portions of the cores which are adjacent the surfaces of the tubes, is reduced substantially in thickness as indicated at 15' in Fig. 6, and may be substantially eliminated.

The soft flowable metal comprising the coatings 15 of the four core strips C_5 and C_6 unite with one another to form a substantially unitary core structure having out and inner portions C_7 and C_8 as shown in Fig. 6, and not unlike the unitary core structure previously described in connection with Fig. 4.

The application of heat and pressure to the elongated and coated core strips C_5 and C_6 is carried out under such conditions as to prevent the coating metal 15 from adhering to the surfaces of the tubes T_1, T_2, T_3 and T_4. That is to say, there is no uniting of the two metals at their surface junctures by fusing or the like. In fact the coating of soft metal may be made to flow to fill the air spaces existing between the various core elements of Fig. 5 and produce the unitary core structure of Fig. 6 at a temperature below fusion. The avoidance of adhesion of the metals at their surface junctures leaves the tubes T_1, T_2, T_3 and T_4 in condition to slide one with respect to the other when the forces of expansion are applied thereto caused by temperature differences between the various tubes. In fact the employment of a soft easily flowable metal such as soldering alloy may serve as a lubricant to aid in the elongation or contraction of the various tubes.

It will be observed that the modified core strips C_5, although having a different cross section from core strips C_1 are formed to have an outward bulge along the outermost surfaces as indicated at 16, so that the binding B at all times tends to force the core strips inwardly.

Referring now to Figs. 8 and 9, there is here shown a modification of the elongated core strips which is intended more particularly for use with the narrow bindings B_1 or B_2 of Fig. 2. The outer elongated core strips C_a may be made of a flowable metal such as soft copper, as described in connection with Figs. 3 and 4, or of a harder metal provided with a coating of soft metal, as described

in connection with Figs. 5 and 6, but are in addition provided with a backing strip 17 of a stiffer metal such as steel. This backing strip extends continuously throughout the length of each of the elongated core strips and serves to distribute the binding pressure from the spaced narrow bindings B_1 or B_2, as indicated, for example, in Fig. 9.

A further modification is illustrated in Figs. 7 and 12. This embodiment of the invention differs from those previously described in that the material forming the heat transferring core, or cores, between the tubes is formed integrally with each of the tubes. Thus the tubes T_5, T_6, T_7 and T_8 have circular bores 18 like the other tubes and also have circular end portions 19 and 20 like the tubes previously described, but their intermediate portions, as shown in Fig. 12, have walls of increased thickness and an irregular cross section, as shown in Fig. 7, these cross sections being so shaped that the four tubes will nest together with flat contacting surfaces throughout their length.

Thus tubes T_6 and T_8 are in contact with one another along flat elongated surface 21. Also tube T_6 engages tubes T_5 and T_7 along flat elongated surfaces 22 and 23, respectively, and tube T_8 engages tubes T_5 and T_7 along similar surfaces 24 and 25, respectively. To accomplish this tubes T_6 and T_8 are in cross section substantially the shape of a modified pentagon with one rounded corner, and tubes T_5 and T_7 are in cross section substantially trapezoidal with one rounded corner. With their flat sides in engagement with one another as described, and as shown in Fig. 7, the binding B may be applied to hold the four tubes permanently in heat transfer engagement with one another, the general outline of the unit in cross section being that of a parallelogram with rounded corners similar to the other forms of heat exchange unit previously described.

The metal added along the central portions of the tubes and extending outwardly beyond the circular outlines (Fig. 7) of the end portions of the tubes serves as core material forming paths between the several tubes for the transfer of heat in a manner similar to the heat transfer in the other embodiments of the invention. If desired the flat elongated surfaces 21, 22, 23, 24 and 25 may be coated with soft flowable material such as solder before assembling the tubes and placing the binding B about them. As in the other forms of heat exchange unit, however, the individual tubes T_5, T_6, T_7 and T_8 are free to slide one with respect to the other under the action of the forces of expansion or contraction.

It will be understood that the end portions 19 (Fig. 12) may be secured in a connecting flange similar to flange 8 in Figs. 1 and 2 and that at the opposite end of the unit, tubes T_6 and T_8 may be connected together by having a return bend similar to return bend 6 welded to their respective end portions 20. Tubes T_5 and T_7 may also be connected in a similar manner. Tubes T_5 and T_7 are identical in cross section as are tubes T_6 and T_8. They may be manufactured by the extrusion process, by casting or by machining.

The improved method of producing the novel heat exchanger of the invention will now be described. Straight tubes of preferably seamless drawn material such as steel, and each one exactly like the other except that certain of them may be slightly shorter than the rest, as indicated in Fig. 1, are placed alongside one another and held against one another in any desired arrangement, such, for example, as that shown in Fig. 3, the two inner elongated core strips C_2 being

inserted between the four tubes. Then the four outer elongated core strips C_1 are added to occupy the elongated spaces between the tubes. The core strips used may be either of a soft flowable metal such as soft copper or aluminum of the type shown in Fig. 3 or of the type shown in Fig. 5 in which the elongated core strips, either of soft or of hard heat conductive metal are coated with a layer of soft flowable metal such as solder alloy.

The assembled parts may then be subjected to a temperature which is sufficient to soften either the core strips themselves or the soft metal coating upon them and while in this softened condition the binding B is applied and under the pressure which accompanies the winding of the binding wire, the metal is caused to flow so as to fill the interstices between the tubes, as previously described and as shown in Fig. 4 or 5.

If desired the application of pressure may be by means independent of the binding, as, for example, in a suitable machine, or by hydraulic pressure, and while the assembled parts are subjected to such pressure the application of the binding may be made. This procedure is especially convenient where binding, such as indicated at B_2 in Fig. 2 is used, which, instead of being made of wire, consists of metal bands, the ends of which are fastened together by welding or some effective locking means. The pressure may be applied while the cores are undergoing softening rather than waiting until after they have become soft.

Furthermore the core material or the coating thereon may be of sufficiently soft material to be worked cold, that is to say, at ordinary temperatures, so that the step of applying heat to raise the temperature until softening takes place as implied in the method above described, may be omitted. Under these circumstances after the assembly of the tubes and core strips as described, the metal of the core material is caused to flow so as to fill the interstices between the tubes entirely by the application of external pressure to the assembled tubes and core strips either mechanically or hydraulically. Thereupon binding may be applied as previously described.

As a further modification of the improved method, the core strips, and particularly when coated core strips are used the coating itself may be of metal such as solder which fuses at comparatively low temperature, much below the softening temperature of the metal of the heat exchanger tube. Then after the assembling of the tubes and core strips it is merely necessary to raise the temperature of the assembly substantially to the fusion point of the fusible metal. Then the forces of gravity and capillarity will cause the spaces and interstices between the ends of the core strips and between the tubes to be filled with the fused metal. Thereafter the binding may be applied.

After the binding has been applied, the right hand ends of the four tubes may be expanded into the respective apertures of flange 8 and the return bends 6 and 7 welded in place at the opposite end of the unit. Prior to the application of these return bends, however, the ends 13 of tubes T_2 and T_4 are bent outwardly, as indicated in Figs. 1 and 2, to form offset portions, which between them provide room for the reception of return bend 7 of the other two tubes T_1 and T_3.

By means of the present invention there has been provided a heat exchanger unit which is

well adapted for use at both high pressures and high temperatures and which provides for the efficient transfer of the heat from the comparatively hotter fluid to the cooler fluid. It is compact and comparatively light in weight and can be used successfully where the difference in temperature between the comparatively hot fluid and that of the cooler fluid is not limited to a few hundred degrees Fahrenheit, as is necessary in constructions where the tubes are fixedly secured together.

It should be understood that the embodiments of the invention selected for illustration are but typical of various forms in which the invention may be carried out and that the invention is not limited to the details of construction disclosed except insofar as set forth in the appended claims.

I claim:

1. The method of constructing a heat exchanger unit which comprises assembling in parallel relation to one another a plurality of metal tubes and core strips, at least an outer portion of each strip consisting of a metal having a lower softening temperature than that of the metal of said tubes, said core strips being disposed in the pockets between said tubes and extending substantially from end to end thereof, subjecting the assembled parts to a temperature sufficient to soften the soft portions of said strips, and applying a binding to said unit thereby causing said softened material to flow and completely fill the spaces between said tubes.

2. The method of constructing a heat exchanger unit which comprises assembling in parallel relation to one another a plurality of metallic tubes and core strips, a surface portion of each strip consisting of metal having a fusing temperature which is lower than that of the metal of said tubes, said core strips being disposed in the pockets between said tubes and extending substantially from end to end thereof, subjecting the assembled parts to a temperature sufficient to cause portions of said strips to flow and completely fill the spaces between said tubes, and thereafter applying binding to said unit.

3. The method of constructing a heat exchanger unit which comprises assembling in parallel relation to one another a plurality of metallic tubes and core strips, at least a portion of each strip having a lower softening temperature than that of the metal of said tubes, said core strips being disposed in the pockets between said tubes and extending substantially from end to end thereof, subjecting the assembled parts to a temperature and external pressure sufficient to soften the material of said core strips and cause it to flow and completely fill the spaces between said tubes, and applying binding to said unit.

4. The method of constructing a heat exchanger unit which comprises assembling in parallel relation to one another a plurality of metallic tubes and core strips at least a surface portion of which is softer than said tubes, said core strips being disposed in pockets between said tubes and extending substantially from end to end thereof, and subjecting the assembled parts to heat and pressure to cause said strips to flow and completely fill the spaces between the tubes.

WILLIAM BISCH.

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