

Aug. 13, 1946.

C. J. VILLIER

2,405,722

HEAT EXCHANGE STRUCTURE

Filed Feb. 27, 1943

3 Sheets-Sheet 1

Fig. I.

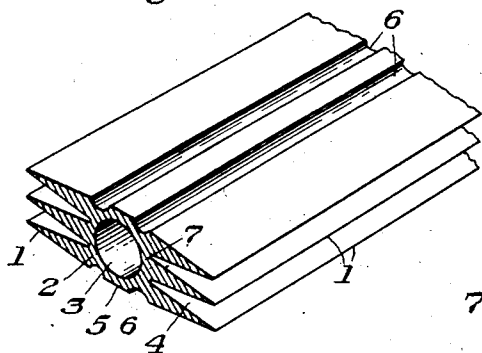


Fig. II.

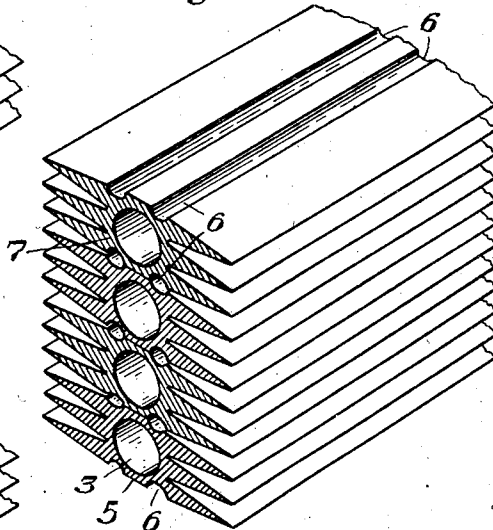


Fig. III.

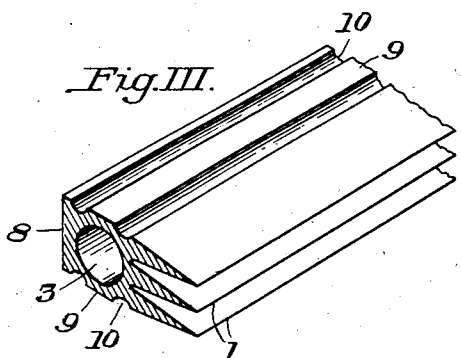


Fig. IV.

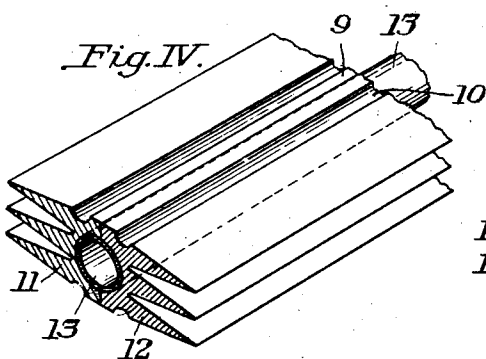
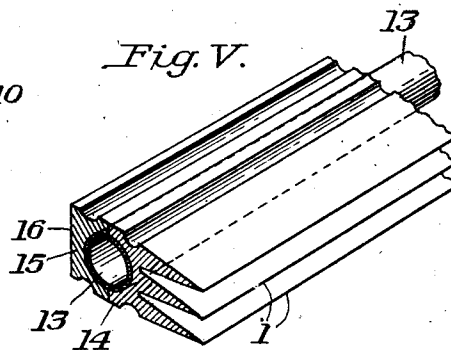


Fig. V.



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Fig. VI.

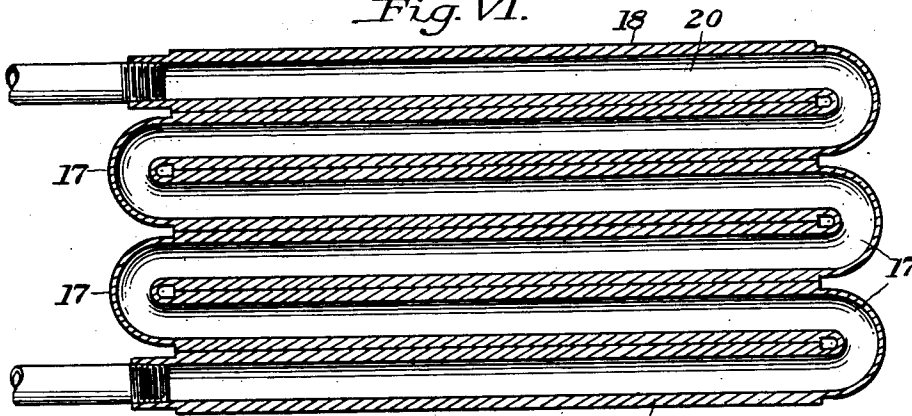


Fig. VII.

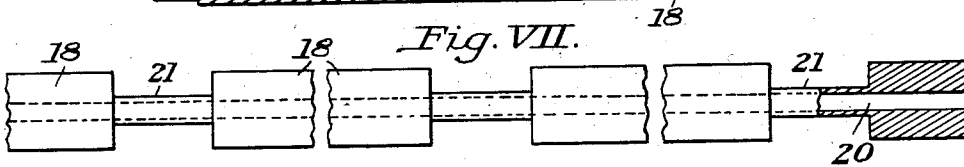


Fig. VIII.



Fig. IX.

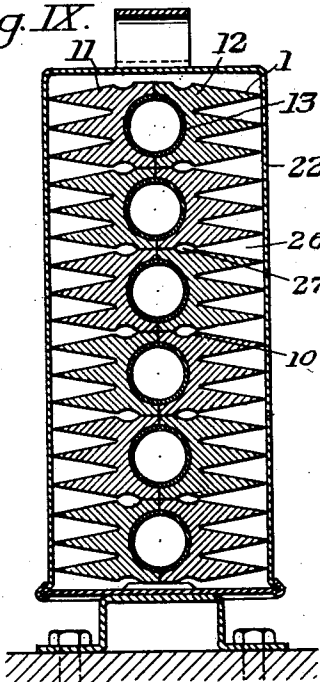
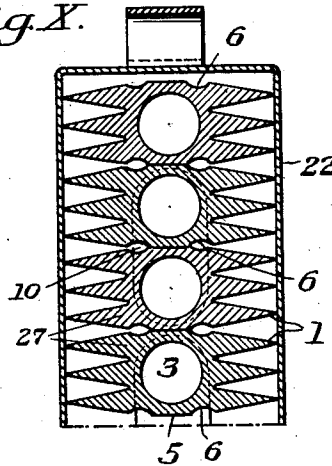


Fig. X.



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Fig. XI.

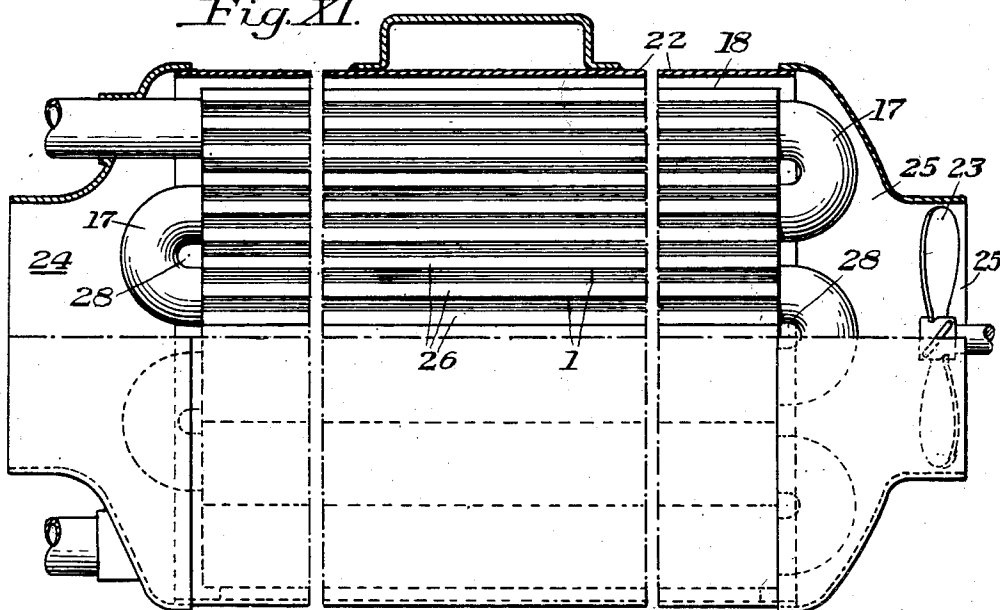
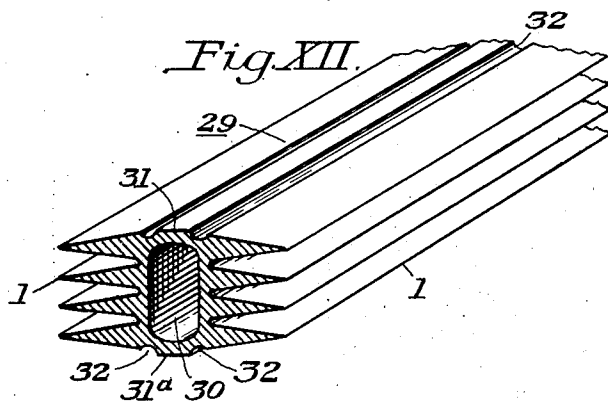


Fig. XII.



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UNITED STATES PATENT OFFICE

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HEAT EXCHANGE STRUCTURE

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7 Claims. (Cl. 257-137)

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This invention relates to heat-exchange devices of the type wherein heat is transferred in either direction between a fluid passing through an enclosing, heat-transferring structure and a second fluid contacting the exterior of the structure.

A primary object of the invention is to provide a tubular heat-exchange element having a cross-sectional configuration that lends itself to formation by readily performed manufacturing methods, that is highly specialized to give heat-transfer of extremely high efficiency; which has a form insuring transfer of uniform quantities of heat to or from the entire external surface area of the element; which is adapted to use in a large number of differently arranged assemblies; which gives an optimum flow of fluid externally of the tubular heat-transfer element; and which gives an extended length of fluid flow interiorly of a cooling unit or system made of a plurality of the heat-transfer elements.

Another object of the invention is to provide novel assemblies of the elements herein disclosed, arranged to take full advantage of the high heat-transfer capacity of such elements.

In the accompanying drawings:

Fig. I is a perspective fragmentary view showing the structural arrangement of a heat-transfer element in accordance with my invention.

Fig. II is a similar view showing a plurality of elements as shown in Fig. I in a stacked arrangement.

Fig. III is a perspective view of a heat-transfer element of modified form.

Fig. IV is a perspective view of a heat-transfer element similar in form to the element shown in Fig. I, but made sectionally and equipped with a liner tube.

Fig. V is a view showing a heat-transfer element having the modified form of Fig. III, made sectionally and equipped with a liner tube similarly to the structure shown in Fig. IV.

Fig. VI is a longitudinal sectional view through a plurality of heat-transfer elements in accordance with Fig. I, showing interconnection between elements to provide a continuous duct for fluids therethrough.

Fig. VII is a schematic plan view of a length of heat-transfer element in accordance with my invention, illustrating one mode of manufacturing the elements to provide a continuous duct for fluids as shown in Fig. VI.

Fig. VIII is a schematic plan view illustrating a modified mode of manufacturing the heat-

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transfer elements to provide a continuous duct for fluids.

Fig. IX is a vertical sectional view through a plurality of heat-transfer elements formed as in Fig. IV assembled to provide a heat-transfer unit assembly.

Fig. X is a fragmentary similar view of an analogous assembly, showing heat-transfer units in accordance with the showing of Fig. I.

Fig. XI is an elevational view, showing a heat-transfer unit assembly as in Figs. IX and X, with the casing of the unit assembly partially broken away to show the general organization of the assembly.

Fig. XII is a perspective view of a further modified form of heat-transfer element.

Heat-transfer structure in accordance with my invention, as is usual in apparatus of that class, is purposed to effect heat-transfer between two fluids, which may be water or other liquid, air or other gas, steam, or other like or unlike matter in fluid state. The tubular element disclosed in Fig. I is of cross-sectional configuration that will produce a uniform heat-transfer to or from a stream of fluid flowing through it and all parts of its external surface. Consequently, heat-absorption by the elements from a surrounding hotter fluid, or dissipation of heat to a cooler surrounding fluid, and transfer of such heat through the body of the element will be at a uniform rate in all directions from the bore of the elements to give heat-transfer of exceptionally high efficiency.

To accomplish this uniformity of heat-transfer, the tubular body of such an element is provided with longitudinal outwardly tapering fins or flanges 1, designed not only to provide a relatively large external surface area as compared to the area of the internal surface 2 surrounding the bore 3, but tapered in such a ratio of flange thickness to distance from the surface 2 as to provide throughout each flange such mass of heat-transferring material as to maintain the entire external surface of the element at a uniform temperature. Heat-absorption or radiation of the entire surface of the element is thereby made uniform, making possible a full utilization of the heat-transmitting capacity of the material of which the element is made. The flanges 1 are separated by channels 4.

Since the tubular elements are adapted for stacking in directly contacting relation, the flanges 1 of such an element are not arranged in uniform radiating arrangement around the bore of the element, but are arranged in two series

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projecting outwardly upon opposite sides of the element. In order that face-to-face contact may be established in the manner shown in Fig. II, the elements are provided with opposite matching unflanged surfaces 5 extended between the outer surfaces of the bases of the marginal flanges. These surfaces 5 are provided with longitudinal grooves 6 which provide passages for the external fluid when the surfaces 5 of two elements are brought into contacting relation, extended inwardly from the channels 4 between the flanges. This provides for heat-transmission to or from the portions of the surface 2 lying between the areas correlated with the flanges. The grooves 6 and the channels 4 extend inwardly toward the bore 3 such distances as to provide between their bases and the bore what is in effect a round tubular body wall surrounding the bore, which wall is designated in the drawings by reference numeral 7. The arrangement of the flanges 1, channels 4, and grooves 6 is such as to maintain this wall structure 7 at an approximately uniform temperature throughout its extent around the bore.

Elements having the configuration shown in the various forms of Figs. I to V may be made by extrusion or casting, the former method being preferred in that it permits production of extended lengths which lend themselves to formation of certain types of heat-exchange assemblies. The elements may be made of any material having suitable high capacity for heat-transfer and that can be formed in the required shape. The currently available extrudable metals of high heat-transfer capacity and high ductility, such as aluminum and copper, are at present regarded as preferred materials. The elements, as extruded, are of uniform cross-sectional configuration throughout their lengths.

Figs. I to V disclose various forms that elements having the configuration described may take. These various modifications are useful in different sorts of heat-exchange devices, and their selection depends upon the arrangement of the particular device and the type of service for which it is intended.

Whereas the heat-transfer element shown in Fig. I comprises a one-piece tubular section, in Fig. III the element corresponds approximately to one-half the tubular form of Fig. I. In it there is but one group of heat-conducting flanges 1, which lie opposite a third unflanged face 8. The face 8 is flat, or is otherwise formed to match a surface against which the heat-transfer elements are mounted. This form of element also has in its opposed matching faces 9 grooves 10 corresponding to the grooves 6 of the form of heat-transfer element shown in Fig. I.

For making up heat-transfer elements of composite structure, the tubular elements may be extruded, or otherwise formed, in two sections. Desirably, like complete sections, these semi-tubular elements are extruded from a suitable extrudable metal of high heat-transfer properties, such as aluminum. As shown in Fig. IV, two such semi-tubular elements, designated 11 and 12, may be assembled in opposed relation to form a complete tubular element of the same form as the one-piece element of Fig. I, the elements being suitably secured together as by brazing, soldering, or welding, and in assembly enclose between them simple light-walled tubing 13. Such an assembly is particularly useful when the fluid to be passed through the element is reactive with the material of which the element

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is formed, since the tube 13 may be made of a material that is inert to the fluid. A structure having substantially the same ultimate advantages may be made by internally coating the bore of the one-piece element in Fig. I with a suitable coating material, or by lining it in any other suitable way, for example by expanding a seamless ductile tube within the bore.

Fig. V shows a semi-tubular section 14 assembled with a second, modified semi-tubular section 15. The section 15, instead of being provided with a series or group of flanges, has an unflanged lateral surface 16 which is arranged substantially opposite the group of flanges 1 in assembly. As shown in Fig. V, the heat-transfer element is formed of the partial sections 14 and 15 connected around and embracing the light-walled tube 13, to give a composite structure in which the general organization shown in Fig. IV is applied to an element having the form shown in Fig. III.

Tubular elements, such as those shown, may be used with great advantage in heat-exchanging devices generally. The cross-sectional form of the elements permits their formation in a variety of ways into compact heat-exchange devices having peculiarly stable and strong construction, which permits the employment of highly ductile material in the elements without production of fragile structures. The configuration of such devices is also such as to present minimized resistance to fluids flowing through them, and longitudinally along their exterior surface.

Referring to Figs. II and VI, it will be seen that the device comprises a vertical stack of tubular heat-exchange elements, or reaches of heat-exchange elements, designated in assembly by reference numeral 18, which are arranged in directly contacting superposed relation. The internal bores of the tubular elements or reaches 18 are connected by U-shaped tubular connections 17. Such connection may be made in several ways.

In the form shown in Fig. VII a continuous tube is bent to serpentine form, having parallel straight reaches 18 that are connected at their ends by the U-shaped bends 17. The bore 20 through the stack is thus continuous, and in the straight, mutually contacting reaches 18 has the heat-transferring jacketing provided by the flanges 1. In preparation for bending, the tubular structure is stripped of its flanges in a plurality of longitudinally spaced regions 21, and is brought to a simple round section as by grinding, turning, or some similar operation. These stripped regions 21 are utilized to provide the bends 17.

As shown in Fig. VIII, a long assembly structure is made by mounting a series of flanged heat-transfer elements in spaced relation on a tube 13, the regions 13a of the tube lying between the flanged elements providing simple tubular structure for making the bends. This assembly may be made in at least two different ways. In accordance with one method of manufacture, flanged heat-transfer elements as shown in Fig. I are skipped along the tube into properly spaced positions, and the tube is then expanded into secure engagement with them and is bent. Alternatively, heat-transfer elements longitudinally divided into two sectional parts are placed in matched position to surround tube 13 at spaced intervals, and are secured in position as by welding, or brazing, to leave between them the free tube regions 13a

for the connecting bends 17. The showing of Fig. VIII is thus consistent with the application to tube 13 of heat-transfer elements in accordance with the showing of Fig. I and Fig. IV. It is to be understood, however, that heat-transfer elements 5 formed as in Fig. III or Fig. V similarly may be applied to surround the inner tube 13.

With any of these forms, the structure is so bent as to provide a continuous serpentine tube, in which as shown in Fig. VI the straight reaches 18 10 are of finned, or flanged, structure and the bends 17 are of simple tubular structure. As shown in Fig. VI and other figures of the drawings, unflanged faces of the flanged heat-transfer lengths are brought into stacked relation to form a compact assembly, the continuous serpentine bore, or duct, of which is of relatively great length. The advantage derived from utilizing extruded lengths of heat-transfer structure trimmed at intervals 20 for bending, or in mounting a plurality of sections of such structure on a liner of thin wall tubing, are obvious.

It is to be understood that instead of bending the structure of the heat-transfer element proper, or bending a tube upon which a plurality of the 25 heat-transferring elements are mounted, interconnection between straight lengths of the heat-transfer elements may be made in other though currently less desirable ways.

An important advantage rising from my invention is that in an assembly of the heat-transfer elements to form a heat-transfer unit the heat-transfer elements so match as to provide unobstructed flow of fluid around and along the heat-transfer elements. This will be readily apparent from a consideration of Figs. IX, X, and XI. Fig. IX of the drawings shows a plurality of heat-transfer elements made up as in Fig. IV of the drawings, mounted in stacked and matched arrangement within a casing 22, as a heat-transfer unit. Fig. XI of the drawings shows the structural arrangement of such unit as a whole. In accordance with the showing of Fig. XI a fan 23 draws air through inlet 24 of the casing past the heat-transfer elements to outlet opening 25.

Assuming then that some fluid, such as water, is passed through the serpentine duct 20 provided by the several straight reaches 18 and bends 17 of the heat-transfer structure, it is subjected in passage to the heating or cooling effect of a fluid, such as air, drawn through the casing. The air flow (referring to Figs. IX and XI) is through the longitudinal passages 26 between flanges 1 of the heat-transfer elements and through their extensions 27 formed by the grooves 10 in the matching faces of the heat-transfer elements. This flow is uninterrupted longitudinally of the reaches of the heat-transfer elements, because of the longitudinal arrangement of the heat-transfer flanges 1 which they carry. This prevents the formation of eddies and regional vacuum effects which serve greatly to impair heat-transfer in conventional radiator structures.

In a structure wherein a fluid is forced at right angles past a series of straight tubes, a turbulence is set up, tending to produce a vacuum covering a rear segment of each tube through its entire length so that heat is absorbed or dissipated only at the front and sides of the tube. In a heat-transferring assembly utilizing the heat-transfer elements of my invention, there are no "dead" spots caused by vacuum, inasmuch as air flow through passages 26 and their extensions 27 is along the reaches of the heat-transfer elements, 75

and is in contact with a great surface area of metal forming the structure of the heat-transfer elements in its passage. In an assembly such as is shown in Figs. IX and XI, the only vacuum effect present is in regions 28 immediately to the rear of the bends 17. Also considering Figs. IX and XI of the drawings, it will be seen that the circuitous serpentine path which fluid in the duct of the structure is caused to follow gives an extended travel, during all of which the fluid is subjected to heat-transfer under conditions of high heat-transfer efficiency.

Fig. X of the drawings shows in fragmentary manner an assembly such as that shown in Fig. IX, except that the form of heat-transfer element is as shown in Fig. I, rather than as shown in Fig. IV, the bore through the straight reaches of the heat-transfer element proper being formed by its own structure without a liner tube, and interconnection between the ends of the elements being provided as in Fig. VII, or in some other suitable manner.

In making up composite elements such as those responding to Figs. IV and V which include a liner tube of heat-transfer material, the composition of the tube may be adapted to the fluid which the element is expected to receive. Thus if a heat-transfer unit is purposed to contain a fluid which exerts a destructive effect on the metal of which the heat-transferring elements, or jacket structure of the assembly is composed, the tube may be of an unlike metal inert to that fluid. This gives great flexibility in the selection of metals for the primary structure of the elements, while insuring against rapid destruction of the elements under particular service conditions. Conversely the chemical properties of the outer elements, or jacket, of the assembly may be made of metal resistant to a fluid which would attack the liner tube of the assembly.

Fig. XII of the drawings shows a modified form of heat-transfer element which is closely analogous to the heat-transfer element shown in Fig. I. In this heat-transfer element, designated generally by reference numeral 29, the bore 30 through the element is elongate instead of circular, and an increased number of heating flanges 1 are provided. The matching faces 31 and 31a of the heat-transfer element are provided with longitudinal grooves 32 to form continuations of the passages between the flanges 1 when the heat-transfer elements are stacked in matching assembly. This modified form of heat-transfer element is included to illustrate changes which may be made in the structural arrangement of the heat-transfer element while retaining the novel features of the heat-transfer element shown in preceding figures of the drawings.

It will readily be understood that an assembly such as is shown is exemplary only of many assembly arrangements in which heat-transfer elements may be incorporated. It is, however, an inherent characteristic of my heat-transfer elements that they are peculiarly adapted to assembly in unit heat-transfer devices, a plurality of which may further be associated. Thus for example in a heating or cooling installation, a plurality of heat-transfer units such as those shown in Figs. IX and XI may be utilized. An assembly of a plurality of serpentine units between two headers may also advantageously be made. Such assembly also presents a very material practical advantage in that it enables selective dismounting of any one serpentine unit by disconnecting it from the headers. Thus a damaged unit can

be replaced without dismantling the entire assembly, as is required in an assembly of straight tubes connected to two spaced headers.

I claim as my invention:

1. A heat-exchange assembly comprising a continuous tube rebent into serpentine form, with parallel straight reaches in superposed relation, the said straight reaches having opposite matching surfaces that respectively contact in face-to-face relation in the straight reaches and having longitudinally disposed laterally projectant heat-transfer flanges, and longitudinally extended grooves in the structure of the said straight reaches adjacent the opposite matching surfaces thereof arranged in the assembly to provide channels for the flow of fluid substantially to equalize heat-transfer in the surfaces matching in face-to-face contact with that in the flanged regions of the said straight reaches.

2. A heat-exchange assembly comprising a plurality of straight reaches of tubular heat-transfer structure arranged in parallel and stacked relation, adjacent ends of successively adjacent reaches of the assembly being interconnected to provide a continuous serpentine duct through the assembly, the said several reaches having opposed surfaces which match in face-to-face contact in the stacked assembly and each reach having at least one other surface which is flanged, and longitudinally extended grooves in the structure of the said straight reaches adjacent the opposed matching surfaces thereof arranged in the assembly to provide channels for the flow of fluid substantially to equalize heat-transfer in the surfaces matching in face-to-face contact with that in the flanged regions of the said straight reaches.

3. A heat-exchange assembly comprising a continuous tube, opposed portions of said tube being substantially straight and parallel, such straight portions being in superimposed contacting relationship, unflanged portions connecting said straight portions and flanges intermediate said unflanged portions, the flanges being coextensive with the straight portions and being symmetrically disposed, each of such contacting portions being provided with a flat surface separated by grooves so that a flat surface of one portion abuts a flat surface of a superimposed portion and whereby the grooves in one portion mate with

the grooves in a superimposed portion to form fluid passageways, a casing surrounding said tube, said casing having openings adjacent said unflanged connections, and a fan mounted in one opening whereby a fluid may be caused to move longitudinally of the straight portions and flanges.

4. A heat-exchange assembly comprising a continuous tube, opposed portions of said tube being substantially straight and parallel, such straight portions being in superimposed contacting relationship, unflanged portions connecting said straight portions, and groups of flanges intermediate said unflanged portions, the flanges being coextensive with the straight portions and one group of flanges alongside a pair of straight portions being symmetrically arranged with another group on the other side of said pair of straight portions each of such contacting portions being provided with a flat surface separated by grooves so that a flat surface of one portion abuts a flat surface of a superimposed portion and whereby the grooves in one portion mate with the grooves in a superimposed portion to form fluid passageways, a casing surrounding said tube, said casing having openings adjacent said unflanged connections, and a fan mounted in one opening whereby a fluid may be caused to move longitudinally of the straight portions and flanges.

5. A heat exchange duct structure comprising an elongate tubular body for separating two fluids for exchange of heat between them; said body having two opposite unflanged surfaces complementary in contour, said unflanged surfaces being joined by two other surfaces at least one of which is provided with longitudinal flanges, each of said unflanged surfaces being provided with longitudinally extending grooves, the base of one of said flanges being disposed adjacent a groove in one of said unflanged surfaces there being a straight flat surface disposed between grooves in each of said unflanged surfaces.

6. A duct as defined in claim 5 wherein one of such surfaces joining the unflanged surfaces is substantially flat.

7. A duct as defined in claim 5 wherein both of such surfaces joining the unflanged surfaces are provided with flanges.

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